VOLUME XXXIV NUMBER 2

BOTANICAL GAZETTE

AUGUST, 1902

THE ELECTRICAL CONDUCTIVITY OF PLANT JUICES.

FRED. D. HEALD.

(WITH TWO FIGURES)

WITH the recent rapid development of physical chemistry, the physiologist has recognized the fact that the application of the methods of physical chemistry to problems of plant physiology is highly important. Already fruitful results have been obtained in a number of lines, and it only remains for future investigations to increase and supplement them. Since "the conductivity of electrolytic solutions stands in direct relationship with certain phenomena," particularly with the osmotic pressure and with the depression of the freezing-point, it has seemed possible that the determination of the electrical conductivity of plant juices, which are themselves electrolytes, might yield interesting results. Some determinations of this character have been carried out, and although the results are not all that might be expected, they are, to say the least, promising, and will be recorded in the following pages.

The conductivity of electrolytes has been an especially prominent subject in the investigations of physical chemistry, so much so that it may almost be called the *Leitmotiv*. The methods of these investigations and the principles established have recently found application outside the province of physical chemistry. A number of instances may be mentioned. The Division of Soils, U. S. Department of Agriculture, has used the electrical conductivity methods for determining the moisture content[1] of

[1] Bulletin no. 6; also no. 12.

arable soils, and also for determining the temperature[2] and the soluble salt content[3] of soils. Oker-Blom[4] has determined the conductivity of blood, serum, and defibrinated blood for cattle and hogs, but rather from the standpoint of the physical chemist than from that of the physiologist. Recently the rate of flow of underground water[5] has been determined by conductivity experiments.

APPARATUS.

Since the apparatus used is probably not familiar to the majority of botanists it will be described more in detail than

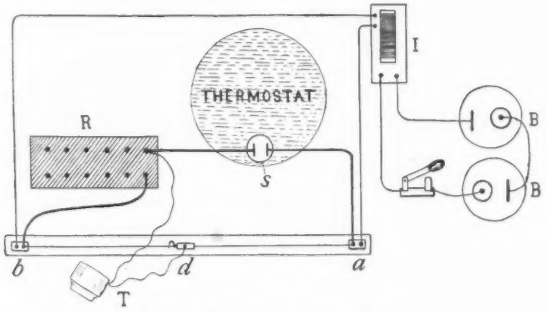


FIG. 1.—For explanation see text.

would otherwise be justifiable. The general plan of the apparatus is represented in *fig. 1*. It consists essentially of a Wheatstone bridge in which the galvanometer is replaced by a telephone (*T*). The resistance is measured along the wire *adb*, which is one meter long, and stretched along a board provided with a millimeter scale. The resistance-box *R* contains resistances of 1, 10, 100, 1000, etc., ohms, and is used for putting into the circuit a resistance nearly equal to that of the electrolytic cell *s*. In order to secure a uniform temperature for all measurements, the electrolytic cell *s* is placed in a thermostat. The windmill thermostat, such as is used in the laboratory of physical chemistry at Leipzig, is the most practical. According to Kohlrausch

[2] Bulletin no. 7.

[3] Bulletin no. 8.

[4] Pflüger's Archives **79**: 111–145.

[5] Science **14**: 972. 1901.

polarization effects can be avoided by using an alternating current of high frequency, and consequently a small induction coil (*I*) of very rapid vibration is added, which serves to transform the current derived from the batteries (*B*).

Since the resistance of solutions varies within wide limits, it was necessary to try a number of different kinds of cells before one was found that was adapted to the work in hand. The first form of cell tried is shown in *fig. 2a*. It has a diameter of 2^{cm}, and the platinum electrodes (*e*) are fused into the ends of glass

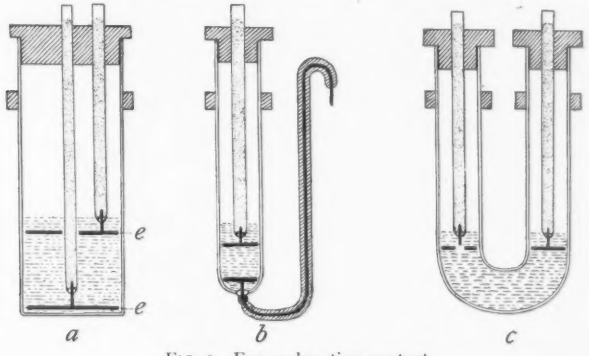


FIG. 2—For explanation see text.

tubes, which are filled with mercury, and securely set in the hard rubber stopper so as to keep the electrodes in a fixed position. The electrodes are covered with a layer of platinum-black by electrolyzing a dilute solution of platinic chloride between them, the object being to increase the surface of the electrodes and thus minimize the polarization effects. This type of cell was found objectionable for two reasons: first, on account of the amount of juice necessary to cover the electrodes; second, because of the small resistance offered, thus making a very indistinct minimum with the telephone. The second form of cell is shown in *fig. 2b*. The diameter of the cell was 8^{mm}, and consequently the resistance of a small amount of solution could be measured, but the minimum obtained with the telephone was indistinct. The form of cell which proved most satisfactory is

shown in *fig. 2c*. In this U-cell the minimum obtained with the telephone was distinct, the amount of resistance inserted in the resistance-box varying from 500 to 2,000 ohms. The diameter of the tube was 6^{mm}, and 5^{cc} of solution was amply sufficient to cover the electrodes.

In order to extract a small amount of juice from the roots, stems, or leaves of plants a special form of press was necessary. This press and the method of obtaining the extract have been previously described.[6]

METHOD.

The capacity of the electrolytic cell must first be determined. This is done by introducing in the cell a solution of known specific conductivity. For this purpose a $\frac{1}{50}$ normal solution of potassium chloride was used, and the thermostat was kept at a temperature of 25° C. This was the temperature at which all subsequent measurements were made, the uniform temperature being necessary, since the conductivity of electrolytes varies with the temperature. After closing the circuit and starting the coil, the movable contact (*fig. 1, d*) is pushed along the graduated resistance *ab* until the minimum for the telephone is found. The resistances are then in the following ratio:

$$R : bd :: s : ad .$$

For the resistance,

$$s = \frac{R \cdot ad}{bd} ;$$

and for the conductivity,

$$\frac{1}{s} = \frac{bd}{R \cdot ad} .$$

The solution used was one of known specific conductivity l, so we have the following relation:

$$l = k \times \frac{bd}{ad \cdot R} \quad \text{or} \quad k = l \times \frac{ad \cdot R}{bd} .$$

$l = 0.002765$,[7] and from the readings made the value of k, or

[6] Jour. Appl. Micr. and Lab. Methods **5**: 1679. March 1902.

[7] LEBLANC, Electrochemie (2te Auflage), p. 77, gives the specific conductivity of $\frac{1}{50}$ normal KCl at 25° C. as 0.002765.

the constant for the cell, can be determined. If now the solution of potassium chloride be replaced by the juice which has an unknown conductivity, and the minimum again found for the telephone, we have the new value from which the specific conductivity can be determined:

$$\text{Specific conductivity} = k \times \frac{bd}{R \cdot ad}.$$

MEASUREMENTS.

With the apparatus and according to the method just described measurements were made to determine the conductivity of the juice obtained from different parts of plants. The following list represents those species used: *Beta vulgaris*, *Solanum tuberosum*, *Allium cepa*, *Raphanus sativus*, *Nuphar advena*, *Cucumis sativus*, *Amarantus retroflexus*, *Portulaca oleracea*.

1. BETA VULGARIS.

A number of preliminary measurements were made with the juice extracted from the blades of the leaves, the petioles, and the roots, with the following result as an example:

	Specific cond. of juice
Blades of leaves	0.03652
Petioles	0.03652
Root	0.01891

It will be noted from these results that the specific conductivity for blades of leaves and petioles is the same, hence in the subsequent measurements leaf-blades and petioles are taken together. In order to determine if there was any relation between the conductivity and the amount of ash present in the juice, the crude ash present in 5 cc of the juice was found. The crude ash was afterwards dissolved in distilled water, diluted up to the original volume of the juice and the specific conductivity of this solution determined. The result is shown by the following:

	Sp. cond. of juice	Crude ash from 5 cc	Sp. cond. of ash sol.
Leaves	0.02676	0.1657 gms	0.0296
Root	0.01349	0.0626	0.01105

The conductivity of the juice from the leaves is shown to be double that obtained from the root, and the amount of crude ash is in accord with this fact, although the juice from the leaves has a little more than twice as much crude ash as is found in the juice from the roots. Since perfectly pure water may be considered as practically a non-conductor, it is evident that the conductivity of the juice obtained is due to the substances that were dissolved in the cell sap. From the results obtained for the specific conductivity of the solution containing the ash, it will be seen that the conductivity is due in large measure to the dissolved salts, and that the organic products have played only a slight part if any.

It may be noted here that these facts are in accord with the general statements in regard to the ash content of plants:[8] "that the proportion of ash increases from the root upwards to the leaves." The different varieties of *Beta vulgaris* analyzed by Wolff[9] showed that the leaves contained a much larger amount of crude ash than the roots. It would seem then that the conductivity measurements are here a rough estimate of the relative amounts of ash present in roots and leaves. It must not be forgotten, however, that the juice obtained would not contain all the ash, since some constituents of the ash exist in the plant in the form of insoluble compounds.[10]

2. SOLANUM TUBEROSUM.

Young vigorous plants grown on a heavy black loam were used and measurements made for the juice extracted from the leaves, the aerial stems, and the tubers. The results obtained were as follows:

	Sp. cond. of juice	Crude ash from 5cc	Sp. cond. of ash sol.
Leaves	0.01959	0.0906	0.01857
Aerial stems	0.02449	0.0781	0.02031
Tuber	0.01505	0.0623	0.01516

[8] VINES, Physiology of plants, p. 130. 1886.

[9] WOLFF, Aschenanalysen, pp. 76–77.

[10] VINES, Physiology of plants, p. 131. 1886.

The specific conductivity for the aerial stems is higher than that for either leaves or tubers, while the amount of crude ash follows the general law already stated that the amount of ash increases from the roots upwards to the leaves. Repeated determinations of the conductivity of the juice taken from different specimens showed similar results, hence it is evident that the conditions here are different from what was found for *Beta vulgaris*. Considering only the tubers and the leaves, the results again show the conductivity to be a rough estimate of the relative amount of ash; but for the aerial stems the conductivity is higher than it should be if ash alone is concerned. How then is the greater conductivity of the juice from the aerial stems to be explained? It is quite probable that it is due in part at least to the greater amount of organic acids present. Titrations of the juice are extremely difficult on account of the color, even when the juice is considerably diluted, but the titrations made indicated more acid than in either leaves or tubers, which are rather alkaline. This conclusion is also substantiated by the specific conductivity of the ash solution, which is considerably less than obtained for the original juice. The relative amount of ash obtained by Wolff[11] for leaves and tubers was slightly different from the above table. His analyses show that the leaves contain nearly three times as much crude ash as the tubers, but a considerable difference was shown by plants taken at different periods in their growth. The different proportions obtained may then be due to the different times and conditions of growth.

3. Allium cepa.

The juice obtained from both leaves and bulbs was measured with the following results:

	Sp. cond. of juice	Crude ash from 5cc	Sp. cond. of ash sol.
Leaves.....	0.0125	0.047	0.00921
Bulb.....	0.00525	0.0229	0.00446

[11] Wolff, Aschenanalysen, p. 75.

The specific conductivity of the juice from the leaves is shown to be more than twice that of the juice from the bulb, and the amount of crude ash obtained from 5^{cc} of the juice follows about the same proportion. The figures for the specific conductivity of the solution made up from the crude ash indicate that the ash alone was not the cause of the conductivity of the juice, but that the organic compounds were concerned. Other determinations were made for this species, and all yielded practically the same results. It may also be noticed that the specific conductivity of the juice from the stalk or stem of a specimen in flower is but slightly in excess of that obtained from the bulb. The relative alkalinity of the ash solution of leaves and bulb is as 2.5 : 1, which is in agreement with the specific conductivity of the solution. The determinations of the specific conductivity of the juice are thus shown in this species to be a rough measure of the relative amounts of ash present.

4. RAPHANUS SATIVUS.

For the common garden radish only specific conductivity determinations were made, using the juice obtained from leaves and root. The results obtained from two different specimens will show how nearly the specific conductivities correspond.

	I. Specific cond. of juice	II. Specific cond. of juice
Leaves.....	0.02105	0.02055
Root.....	0.02011	0.01833

The difference here between leaves and roots is less than that obtained for any previous measurements, but the conductivity of the leaf juice is still in excess of that obtained for the root. No ash determinations were made for this species.

5. NUPHAR ADVENA.

All of the species used up to this point were taken from places where they had been subjected to about the

same conditions of soil and moisture. It was desirable to make determinations for plants subjected to other conditions, and *Nuphar advena* was selected as a good example of a hydrophyte.

Conductivity measurements and ash determinations were made for the juice obtained from the blades of the leaves, the petioles, the rhizome, and the roots. All parts of the plant used were very carefully washed, and all moisture removed from the surface with filter paper before the juice was extracted. The results obtained are shown in the following table:

	Sp. cond. of juice	Crude ash from 5cc	Sp. cond. ash sol.
Blades of leaves ...	0.009368	0.0328	0.00784
Petioles	0.009368	0.0327	0.00822
Rhizome	0.00761	0.0298	0.00822
Roots	0.006113	0.0226	0.00568

The above measurements show that there is a progressive increase in the conductivity of the juice from the roots through the rhizome to the leaves, the measurements for petioles and blades of leaves yielding the same results. The crude ash determinations show a like progressive increase from the roots upwards. The crude ash was redissolved in distilled water and diluted up to the original volume of the juice, and the specific conductivity of the ash solutions determined. The result obtained for the rhizome ash deviates from what might reasonably be expected, being slightly in excess of that obtained for the juice. The others show a slightly lower conductivity than the original juice, showing that part of the conductivity was due to other than ash constituents.

A comparison may be made of the specific conductivities in this species and some of the previous examples. In *Beta vulgaris* the specific conductivity of the juice from the leaves is

three times as great, in *Raphanus sativus* it is over twice as great, and in *Allium cepa* still in excess, although the difference is not great. The results were what might anturally be expected when we consider the aquatic habitat of Nuphar.

6. Cucumis sativus.

For the garden cucumber measurements were made for juice extracted from leaves, stem, and fruit. The roots being small it was not possible to obtain the amount of juice necessary to make the measurements. The results are as follows:

	Sp. cond. of juice	Crude ash from 5cc	Sp. cond. ash sol.
Leaves.....	0.0127	0.0621	0.01096
Stem.....	0.0149	0.0609	0.01497
Fruit	0.00632	0.0182	0.00383

This is the only species in which the juice obtained from the fruit was measured, and the examination of fruits of other species is highly desirable. In this instance it will be seen that the specific conductivity found for the fruit is only about half that found for leaves. Here is also another instance in which the specific conductivity of the juice from the stem is greater than that found for the leaves and is not in accord with the amount of crude ash found.

The specific conductivity of the solutions made from the ash of leaves and stem indicates that little besides the ash constituents were responsible for the conductivity of the juice. For the fruit ash, the specific conductivity is but little over half that of the original juice, which indicates that other substances than the ash constituents were concerned. Litmus tests and titrations indicated that the conductivity was produced partly by the acid content of the juice.

7. Portulaca and Amarantus.

Conductivity measurements were made for two more species, and the results will be given together. In each case roots, stems, and leaves were used with the following results;

	Portulaca oleracea Sp. cond. of juice	Amarantus retroflexus. Sp. cond. of juice.
Leaves.....	0.02445	0.01711
Stems.....	0.02154	0.01519
Roots.....	0.01069	0.01328

These figures show that for both species there is a progressive increase in the specific conductivity from the roots upward. No ash determinations were made for either of these species.

The results obtained and recorded in the foregoing pages indicate that a method may be afforded of determining the relative amounts of ash in different parts of the same plant. Conductivity determinations of the juice from the same species grown on different kinds of soil would probably yield interesting results. It is known that the ash of any given species varies in amount throughout the period of growth, and it ought to be possible to determine the extent of the variations by means of conductivity measurements. If this is possible, then the much more laborious process of an ash determination would not be necessary.

It may be noted in this connection that there is a difference of potential between the shoot and root of a plant, the root being electro-negative and the shoot in a state of positive electrification. Whether the greater conductivity of the cell sap in the shoot is in any way connected with this condition remains an open question. The facts at least are suggestive.

CONCLUSIONS.

A number of conclusions can be drawn from the foregoing records of conductivity determinations. Although others are indicated, a greater number of species must be examined before

any more definite relations can be established. From the data at hand the following facts seem established:

1. Plant juices are good conductors, and the conductivity is due in large measure to the dissolved mineral substances, while the organic compounds play a minor part.

2. The specific conductivity of the juice obtained from the roots of plants is always considerably less than that of the juice obtained from subaerial parts.

3. The specific conductivity generally increases progressively from the root upward, although in some cases the sap from the stem has a higher conductivity than that from the leaves.

4. In the majority of cases the specific conductivity is a rough measure of the relative amounts of ash present in different parts of the plant.

PARSONS COLLEGE,
Fairfield, Iowa.

ON THE NATURE OF THE STIMULUS CAUSING THE CHANGE OF FORM AND STRUCTURE IN *PROSERPINACA PALUSTRIS.*

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY XXXVII.

By WILLIAM BURNET MCCALLUM.

(WITH TEN FIGURES)

ALTHOUGH heterophylly in amphibious plants has long been a subject of observation and experiment, as yet we are in ignorance of the real factors that determine which type of leaf such a plant shall assume. The environment of a submerged water plant is certainly a complex one, and there has not been anything like a definite analysis of it. If we are to understand the behavior of a plant when submerged, it is clear that there must be a definite knowledge of the various factors concerned, and of the influence of each one upon the plant. The literature on the subject in the main discusses such topics as water medium, diminished light relations, different oxygen and carbon dioxide conditions, buoyancy, nutrition, and the like; but such terms are general and indefinite, and convey little real information as to the actual factors acting upon the primordial cells of the plant. The demands of physiology can only be satisfied by a detailed analysis of all the possible factors, each of which is a complex in itself, and a determination of the direct action of each resolved component upon the protoplasm of those portions of the plant involved. Of course such an aim is only ideal and at present cannot be realized, but it is, nevertheless, the ultimate goal to be reached before we can read the plant in terms of its environment.

In the hope of obtaining some information upon this question, experiments were begun on *Proserpinaca palustris* in the autumn of 1900, and are still in progress. The plants used have been grown from seed or obtained from the low-lying lands about

Chicago, where they grow abundantly. The work has all been done at the Hull Botanical Laboratory of the University of Chicago, most of the experiments having been carried on in the conservatory. The results are given here only in outline. A

FIG. 1.—Typical air plants, bearing seed.

more detailed account will appear later, when other phases of the work now in progress will be presented.

Proserpinaca palustris grows in low, swampy situations usually flooded in the spring and early summer, and subject to occasional submergence throughout the season. The shoots develop equally well in air and water and present two very distinct forms. When

grown in the air the leaves are lanceolate in outline, 5 to 5.5 cm long and 7 to 8 mm broad, with margins rather finely serrated (*figs. 1* and *3*). The structure is that common to air leaves—that is, thick cuticle, abundance of stomata on the under surface, strong development of palisades, and a well-developed vascular system (*fig. 5*). In the stem there are the usual vascular and mechanical tissues, cortex, etc. The whole form and structure is that of a typical aerial shoot.

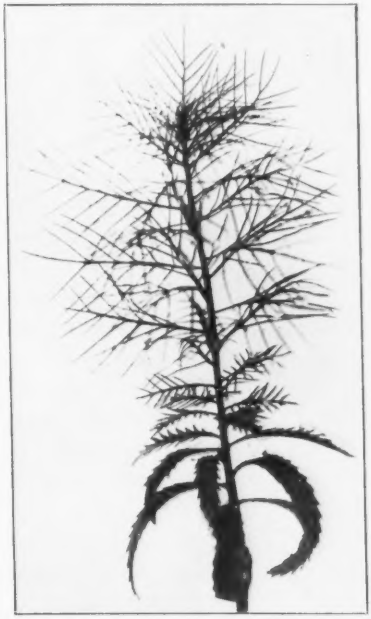


FIG. 2.—Water form in nutrient solution.

When submerged the shoots that develop are entirely different. The leaf is finely dissected, consisting of a slender central rib, with from three to five thread-like lobes on each side (*figs. 2*, *4*, and *8*), which are often only about 0.2 mm in diameter, and may become 2 cm long. These filamentous divisions are cylindrical in cross-section, and show almost an entire absence of stomata; the epidermal cells are very small and without any trace of cuticle, the outer walls being thin and delicate (*fig. 6*). There is an absence of any sort of differentiation in the mesophyll, no trace of palisades appearing. The chlorophyll has a marked peripheral placement, the outer cells, which are spherical, being packed full, while the inner ones have almost none. The mesophyll is very loosely arranged, and with a copious development of air chambers throughout. The dry weight is just one-tenth that of the air leaf. There is an entire absence of any sort of mechanical tissue or of xylem, both of

which are conspicuous in the air leaves. The vascular system is represented only by a weak development of phloem. The stem of the water form is traversed by large and conspicuous air chambers that connect with the leaves and the roots. The mechanical tissue so conspicuous in the air form is absent altogether, nor can any trace of conducting tissue be seen. In the axils, and along the leaf margins, and terminating each lobe, are gland-like structures that possibly function as hydathodes.

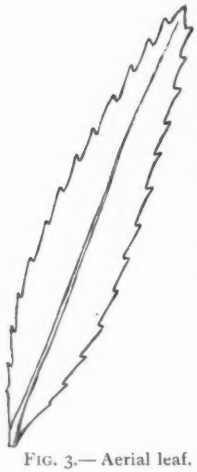


FIG. 3.— Aerial leaf.

No attempt will be made here to give any account of the literature. A good deal of work has been done upon other amphibious plants, but the object of this paper is merely to present some results of experiment on Proserpinaca, and the literature will be passed over by merely mentioning a few of the more conspicuous investigations upon the general subject.

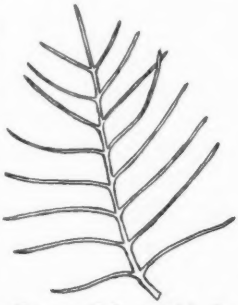


FIG. 4.— Submerged leaf.

Mer[1] considers the aquatic form as due in the main to weakened illumination and nutrition. Constantin[2] regards it a result of the weakening of vegetative activity. Schenck[3] considers it largely a question of the relation to light and to food absorption. Goebel, while recognizing the com-

[1] MER E., Des causes qui modifient la structure de certain plantes aquatiques végétant dans l'eau. Bull. Soc. Bot. France **27**: 194. 1880.

[2] CONSTANTIN, J., Observations critiques sur l'epiderme des feuilles des végétaux aquatiques. Bull. Soc. Bot. France **32**: 83. 1885.

Recherches sur la structure de la tige des plantes aquatiques. Ann. Sci. Nat. Bot. VI. **19**: 287–331. *pls. 14–17*. 1884.

Etudes sur les feuilles des plantes aquatiques. Ann. Sci. Nat. Bot. VII. **3**: 94–162. 1886.

[3] SCHENCK, Vergleichende Anatomie der submersen Pflanzen. 1886.

plexity[4] of the conditions, regards light, or rather the lack of light, as the chief factor. Wachter[5] substantially agrees with Goebel.

There seems to be thus an almost universal tendency among writers to attribute the difference in structure between aerial and water forms to differences in light or nutrition, especially the former. These terms, however, are very general, especially nutrition, which involves so much as to mean little in the way of explanation. Ultimately, there must be a critical analysis of the conditions present in the water medium, of the individual factors there that can act upon the growing cells, and the effect of each of these on the behavior of the primordia.

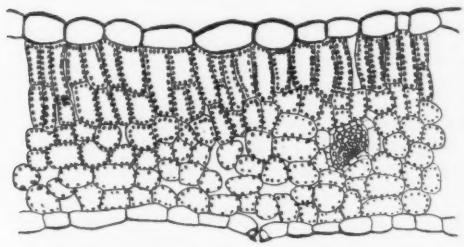


FIG. 5.— Cross section of aerial leaf.

Every living cell in a plant is surrounded at all times by a thin membrane of water through which all substances entering the cell must pass in solution. No substance, be it salt, organic compound, or gas, can enter or leave the cell in any other way than by diffusion as a solute through this film of water. When a plant is submerged this membrane is extended, its thickness

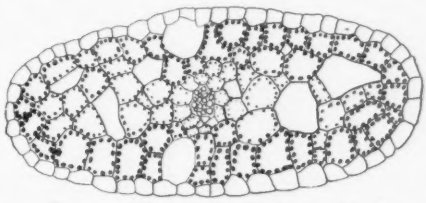


FIG. 6.— Cross section of submerged leaf.

[4] GOEBEL, K., Pflanzenbiologische Schildenungen. Part II. 1891.

Ueber die Einwicklung des Lichtes auf die Gestaltung der Kakteen und anderer Pflanzen. Flora **80**: 96–116. *figs. 5.* 1895.

Ueber der Einfluss des Lichtes auf die Lestaltung der Kakteen und anderer Pflanzen. Flora **82**: 1–13. *figs. 4.* 1899.

[5] WACHTER, W., Beitrage zur Kenntniss einige Wasserpflanzen. Flora **83**: 343–348. 1897.

being the depth beneath the surface of the water; and all gases, etc., and light which reach the cell from the exterior must pass through this increased thickness of water. What different conditions are here introduced, capable of modifying the life-phenomena of the cell? Until we have a definite knowledge of what these conditions are, *i. e.*, of the different physical conditions involving the entrance of gases, salts, or light through water measured by fractions of a millimeter or by centimeters, we cannot hope to know much about the difference in the environment of the cell in air and in water.

Merely for the sake of convenience in discussion, we may arrange what seem to be the possible factors acting upon aquatic plants under the following heads: nutrition, light, temperature, gaseous content of water, substances in the water, and what seems to have altogether escaped notice, the influence of the water itself, either acting as a contact stimulus (stereotropism), or by diluting the cell contents and protoplasm. Of course, such a classification of factors is essentially superficial. It would be quite erroneous, for example, to consider nutrition apart from light which involves photosynthesis, or from temperature, or gas exchange, or absorption of salts; but it will enable us to discuss the matter more systematically and with greater clearness. It is to be understood that the experiments are given here only in outline.

1. LIGHT.—A large number of experiments were conducted. Plants were grown in the strongest sunlight available, and in darkness, and in all stages between, the experiments always being duplicated in water and in air. Plants were also grown in various depths of water. The results were always uniform; the light apparently having no influence whatsoever on the character of the developing shoot. When in the water it produced the water form, and in the air the air form, regardless of the illumination. Plants with their tips the merest fraction of an inch beneath the surface, in both strong and weak light, produced the water form; and those with their tips just above the water produced the air form, no matter what the illumination (*fig.* 7).

These experiments were done many times, with many plants and always with the same result. Objection may be raised that light passing through water is not quite the same as that obtained by shading; and to make sure, plants were grown under double walled bell-jars with the space between the walls filled with water, so that all light coming to the plants had to pass through 2 to 3 cm of water. The behavior here was precisely the same as in the other cases, *i. e.*, if the growing tip was in the air, the air form was produced, even when the experiment was conducted in very subdued light. When conducted in bright sunlight the only difference observed was a more vigorous growth. These experiments show that the illumination neither directly, nor indirectly by any subsequent changes that it may involve, can play an essential part in the stimulus to the water form.

FIG. 7.—Submerged plants in very good and very poor illumination.

2. NUTRITION.—One must hesitate before using this term. It is so very vague and indefinite that its chief advantage lies in its convenience in covering a mass of ignorance. It involves the absorption and the use of oxygen, the absorption of carbon dioxide, and the formation of carbohydrates, and hence the action of illumination; the formation of proteids and hence the absorption of the various salts, also the migration of food and other substances, and all the factors that control this, the toxic and other effects of various ions which may be present. In

fact, the entire list of chemical and physical phenomena occurring within the cell, diverse and complicated as these are, and all the factors which can influence them are involved in nutrition. Disturbances in these nutritive relations may be invoked by the slightest increase or decrease in any of the factors concerned. The change in concentration of a single ion may result in profound changes in the cell. And if the water form of Proserpinaca is in any way involved in the nutritive relations it must be because there is some factor, however slight, acting in the water that is not acting in the air.

This we have seen cannot be connected in any way with the light relations. The other possible factors are the relation to temperature, to absorption of salts or ions, to carbon dioxide, or to oxygen. To state, as is not uncommon, that such a phenomenon is due to an increase or decrease of the general nutritive condition of the plant is, of course, merely to say that it is due to a change in one or more of these factors. Experiments were conducted to see what effect these, as they are present in the water, have on the behavior of the plant when submerged.

3. TEMPERATURE.—Most of the experiments were conducted at the ordinary temperature of the conservatory. During the winter some were kept at temperatures so low as almost to inhibit growth, this occurring very slowly. Plants also were kept near the hot water pipes at a temperature so high as occasionally to kill some. In the summer the highest temperatures in the sunlight were used. In all of these cases duplicate experiments were conducted, some in air and some in water, so that the temperature for the two was the same. Some were entirely submerged, some with their tips just above water, some entirely in the air, and some in the air with their tips bent over into the water. In all cases the form of the leaf assumed had no relation to the temperature; as long as any growth occurred the growing points beneath the water produced the water form. In one case two tips at precisely the same temperature were not a centimeter apart, one beneath water and the other above with all the rest of the plant submerged, and the former produced water leaves,

while the latter developed the air form. In general, the *optimum* temperature for the two forms, so far as could be observed, is about the same. This indicates that temperature, in itself, is not a factor in determining which form shall be produced.

4. SALTS.—The relations of carbon dioxide and oxygen to a

FIG. 8.—Plants after being submerged two months.

possible stimulus will be discussed later under another head, as well as the question of food salts. Plants were grown in distilled water, in tap water, and in nutrient solutions. Some were entirely submerged, with their roots in the soil; others had the soil washed away from the roots, and shoots and roots submerged in the water. Some in both distilled and tap water were submerged except the very tips, which were in the air. The same was done in various strengths of nutrient solution. All of these were repeated in strong and weak illumination. The results were invariably the same. The finely divided leaf, with the aquatic type of structure in the leaf and shoot, always occurred when the growing tips were submerged, it mattered not whether in distilled water or in nutrient solutions, or in strong or weak illumi-

nation; while when the tips were in the air the broad leaves were produced whether the rest of the plant was in nutrient solution or distilled water. *Fig. 2* shows a plant grown in nutrient solution, and *fig. 8* shows similar plants in water.

This seems to throw out the general conditions of nutrition, so far as the salts are concerned, as having anything at all to do with the production of the air or the water form. The size of the leaf primordia that can be changed from one form to the other may be mentioned here. The oldest leaf primordia that are still folded in the bud average about 6^{mm} in length. There are usually about nine primordia, and they successively decrease in size, the smallest one that can be readily isolated being 0.2^{mm} long. On the creeping shoots there are about eighteen primordia, the smallest being 0.06^{mm} in length. A complete change from the one form of leaf to the other often occurs within four internodes, which means that a primordium may be turned into either an air or a water leaf after it has attained a length of from 3 to 4^{mm}.

5. SALTS, IONS, ETC., AS A STIMULATING CAUSE.—The presence in the water in solution of any such substance as salts, ions, organic acids, or the like, as a stimulating cause to the water form is conceivable. Its possibility, however, is precluded by the fact that the behavior is the same in redistilled water, and to a certain extent in a saturated atmosphere.

6. RELATIONS TO CO_2 AND TO O_2.—The gaseous content of the water differs from that of the air. The air contains, per $1{,}000^{cc}$, 209^{cc} O and 0.04^{cc} CO_2; while water at 20° C. contains, per $1{,}000^{cc}$, 5.7^{cc} O and 0.3^{cc} CO_2, about $\frac{1}{3}\frac{1}{7}$ the amount of O, and 75 times the amount of CO_2. But the rate of diffusion in the water is much slower than in the air, and the cell may be able to use both gases much faster than the slower diffusion will supply them. The leaves cannot be lacking in oxygen during daylight, for the evolution of bubbles of this gas indicates the excess of the amount generated over that used. But the gas will tend to pass off from all surfaces of the cell equally, and as much per unit of surface will pass into the large and numerous air cham-

bers as is given off from the external surface, and the combined surfaces of the former are often greater than the latter. As these air cavities are continuous through the leaf and stem up into the growing parts, it follows from the laws of diffusion that these latter when illuminated must be supplied with an atmosphere rich in oxygen. This internal atmosphere will vary under different conditions, for during the night, or at times when photosynthesis is not active, the excess of O_2 will diffuse out and CO_2 will accumulate. The gas obtained from stems of *Proserpinaca palustris* growing in deep water and after several days of dull weather contained O_2 4.4 per cent., N 35.6 per cent., CO_2 10 per cent.; and the gas removed from the stems of Nuphar during bright sunshine consisted of O_2 35 per cent., N 65 per cent., CO_2 0.6 per cent.

In the case of CO_2, the slowness of diffusion may counteract the higher percentage in the water. In a perfectly saturated atmosphere, however, where the supply of CO_2 and O is normal, the plant for a long time continues the development of what is essentially the water form. When grown in sugar (lactose) solution the water form is still produced, though in these experiments it has not yet been determined just how much growth has occurred before fermentation has destroyed all the sugar. It is quite possible too that the plant is unable to use the sugar as food.

Plants were grown under water in glass vessels containing atmospheres of different O_2 and CO_2 pressures as follows: (1) one volume of water to an atmosphere containing an equal volume each of CO_2 and O_2; (2) one volume water to an atmosphere of three equal volumes of CO_2 and one volume of air; (3) one part by volume of water to three parts by volume of O_2 and one third part CO_2. For the last experiment the CO_2 pressure was about five hundred times and the O_2 approximately five times as great as that of ordinary atmosphere; while in the second case the O_2 pressure was diminished one-third and the CO_2 pressure increased 250,000 times. In all cases the pressure of the mixture was approximately 760^{mm} mercury; and the

experiments were continued long enough to insure the saturation of the water at these pressures, which in the case of O_2 takes about a couple of weeks.

The results of the experiments were that in every case the water form was produced. This shows that the lack of CO_2, at

FIG. 9 — Plants grown first in water, then in air, then in water, then in air.

least, cannot be involved in the stimulus to the formation of the water form, for the amount that diffused into the plant was, at least in the one case, certainly greater than that which it gets from the normal atmosphere. Of course it is possible that the large amount might induce abnormal or pathological changes which would prevent the normal development, but the two smaller quantities produced the same results. While an increased pressure of five times the normal O_2 pressure still results in the water form, it is possible that still higher pressure might act differently. This is not probable, however, for two reasons: (1) the plants

during these and other experiments during the day gave off O_2 freely, and this could only occur when the cells are making more than they can use and the protoplasm is supersaturated, probably even more than in the air where the O_2 passes off with less resistance; (2) because of the behavior in moist air where

FIG. 10.— A plant whose upper leaves have developed in saturated air.

the plants have the same amount of oxygen as usual in the atmosphere.

7. MOIST AIR.—The water medium necessarily has the effect of entirely checking transpiration, so that its passage from the cells is entirely prevented, and the cells and protoplasm are filled to their utmost capacity with water. This condition, to a certain extent, can be imitated by growing the plants in an atmosphere saturated with water vapor. Such a thing as a perfectly saturated atmosphere, so far as the plant is concerned, is necessarily impossible, for the temperature of the plant is always slightly higher than that of the surrounding medium, and so evaporation

from it must occur. In a large number of experiments considerable variation in this respect was noticed. Some plants when transferred from the air into a moist chamber showed little change, while others developed leaves somewhat intermediate between those and the water leaves. Some, where extra precaution to keep the atmosphere as near saturation as possible and free from changes of temperature, produced essentially the water form, as in *fig. 10*. The lobes are not so long, but the form is the same. In the case of plants grown from seed in moist chambers, several have reached as many as thirty-five internodes and are still producing water leaves. In these cases the amount of CO_2 and O_2 is the same as if the plants grew in the ordinary atmosphere, so that here, at least, differences in the amount of these gases cannot be any part of the stimulus to the formation of the water form.

The essential feature common to the water and the moist air is the inhibition of transpiration and the consequent choking of the cells and diluting of the protoplasm with water. This can be tested in another way, *i. e.*, by growing the plants entirely under water and at the same time drawing the water out from the protoplasm; or in reality causing evaporation, or transpiration, by means of high osmotic pressure. Plants producing water leaves were placed in nutrient solutions of a strength not quite sufficient to plasmolyze them; also in very dilute solutions made up to the same osmotic pressure with KCl and also $Ca(NO_3)_2$. These were allowed to evaporate down, becoming gradually stronger. When they reached a strength of solution equal to about a ½ N salt solution the water leaves ceased to form and the air type of leaf appeared. This shows that even under water, if sufficient water be drawn from the protoplasm, the air leaf will be formed. As the amount of light, CO_2, and O_2 is the same here as in the water, and the water type is not produced, it is evident that these form no part of the stimulus to the formation of the water form. Further experiments along this line are still in progress, with other salts and also with non-electrolytes.

8. CONTACT STIMULUS.—The young primordia in the submerged plants are intimately surrounded by water, and it is possible that there might be some contact influence here which checks lateral growth and causes the elongation of the lobes. Contact stimulus (stereotropism) is well known among the lower animals, as, for example, where the rhizoids of some of the hydroid polyps develop as a response to a stimulus of contact from a foreign body. That this cannot be the cause, or any essential part of the cause, is shown by the fact of the formation of the water form in moist air, and also from the facts just mentioned, where this contact is present but the air form is produced.

As to the purely anatomical features of the plant, experimental work is being carried on. A large mass of facts regarding the appearance of the various anatomical features under the diverse conditions of experiment has accumulated and will be presented later. One point only need be mentioned. Besides the positive anatomical characters of the water form, there are what we may perhaps term negative characters, *i. e.*, an absence of certain characters that usually accompany the air conditions. These are the absence of such structures as lignified and cuticularized tissues, stomata, mechanical tissue, and conducting tissue. Experiments are under way to determine to what extent such tissues are dependent upon definite external stimulating causes, and to what extent they will respond if these be supplied under the water.

The results of the experiments so far seem to justify the assertion that the stimulus to the development of the water form in the plant under discussion is not involved in the light relations, in the nutritive conditions, temperature, the gaseous content of the water, nor contact stimulus. The only factor which is constant in all cases where the water form develops is the checking of transpiration and the consequent increased amount of water in the protoplasm. When the protoplasm of the primordial cells is in that condition of dilution which accompanies the absorption of a large amount of water, the nature of the

growth and the orientation of the cell division is such as to produce the water form, while those physical and chemical conditions resulting from a partial withdrawal of water by evaporation (*i. e.*, an increased density of the protoplasm) result in that sort of cell behavior which produces the air form of the plant. Just why this difference in the density of the protoplasm should result in such a different behavior of the cells is a question which this paper does not attempt to discuss. The answer can only come with an increased knowledge of the mechanics of cell division, about which at present we know almost nothing.

One other phenomenon must be mentioned. The results given were all obtained from plants collected outside, which were usually producing the air forms, or else from seedlings grown inside. When some of these had been kept submerged it was noticed that after several months they started to produce the air type of leaf. This only occurred in some cases, and even those in the same aquarium behaved differently. Also in the case of those outside, which were submerged all winter, during May and June many of them succeeded in producing air leaves, though none were able to develop flowers. It would seem here as if some of the plants after a time became accustomed to the stimulus and refused to respond. Or it may be that as only the air form is capable of fruiting, in the effort to produce flowers the plant has the ability of self-adjustment to its conditions and develops the air form in spite of its environment. Examination of these primordia showed that the cells are smaller and the protoplasm denser and less distended with water. It is possible that the protoplasm is able to adjust itself, perhaps by the expulsion of water, into that condition in which it exists when in the air. This, of course, is speculation, but investigations are under way, which it is hoped will give us some information on the subject.

In conclusion, I have pleasure in acknowledging my indebtedness to Professor John M. Coulter, Professor Charles R. Barnes, and to Dr. B. E. Livingston, for much kind assistance and advice.

THE UNIVERSITY OF CHICAGO.

CONTRIBUTIONS TO THE BIOLOGY OF RHIZOBIA.

I. RHIZOBIUM MUTABILE IN ARTIFICIAL CULTURE MEDIA.

ALBERT SCHNEIDER.

(WITH PLATE I)

RECENTLY I began some further work on the biology of rhizobia. The investigations carried on at the Illinois Experiment Station at Champaign in 1893 were terminated before any satisfactory results were reached, and it is only recently that an opportunity has again presented itself to further pursue the investigations.

The review of recent work done in the study of rhizobia will be given in the second paper. A fairly complete list of references up to and including the year 1897 will be found in the *Minnesota Botanical Studies* of September 27, 1894, to which a supplement was added in the *Studies* of May 29, 1897.

Since 1886 numerous investigators, especially those of Germany and France, have attempted to make pure cultures of rhizobia, and some of these have stated repeatedly that cultures were obtained, but not a single investigator has thus far given detailed information regarding them. Other investigators, again, declared that rhizobia were incapable of being grown in artificial media; that they were, indeed, merely plasmic by-products, to which the name *Bakteroiden* was given by Frank and other German investigators. Another source of confusion and difficulty was the fact that most investigators recognized only one form (or species) of rhizobium, namely, the *Rhizobium leguminosarum* of Frank. Without entering again into a discussion of the probable number of species, I shall outline briefly the present preliminary investigations.

I have made repeated attempts to obtain pure cultures of the rhizobia found in the root tubercles of *Melilotus alba*, but with either wholly negative results or only a very evanescent partial success. So frequent were my total failures that I became

almost converted to the opinion that this particular rhizobium was either not an autonomous organism, or that it had lost the ability to grow outside of the host-plant. I have had no difficulty in securing cultures of the rhizobium found in bean-root tubercles, for example, but for reasons which will be given in a subsequent paper I was desirous of obtaining cultures of the comparatively large rod-shaped to Y-shaped form found in sweet clover. For some time after beginning the present series of experiments it appeared that my efforts would again be without positive results; but my former experiences induced me to proceed more cautiously and more carefully, keeping in mind the probable physiological peculiarities of this particular rhizobium as compared with bacteria in general. Now I feel certain that in 1893 I had several small pure cultures of this particular rhizobium, but failed to recognize them, and they were destroyed without being investigated, and, unfortunately, I was furthermore obliged to discontinue the investigations at a time when I was becoming somewhat familiar with my subject.

In the following experiments young seed-grown plants of *Melilotus alba* were selected, which were about four inches high, each plant having from six to fourteen fairly well developed, mostly single, non-branching, more or less irregularly oval to flattened tubercles. The roots and tubercles were thoroughly and repeatedly washed in hydrant water, and dried with blotting paper. A tubercle was cut into with a small sterilized knife, and the knife-blade was lifted, thus breaking the tubercle across. This prevented the blade from dragging exterior bacteria over the interior of the tubercle. A short platinum needle was pushed into the central portion of the tubercle and streak (line) cultures made in Petri dishes with *Melilotus alba* extract solidified by means of agar. The inoculated Petri dishes were kept in the dark at the spring and early summer temperature of the laboratory. Most of the dishes showed white growths in a day or two. Examination proved these to consist of several motile bacteria, including a large motile bacillus resembling *B. anthracis* or *B. subtilis*. In the course of about five days from the time of

making the inoculations I noticed in several of the streaks a very slight, translucent, glistening growth, which at once reminded me of similar growths observed in my former investigations. Upon microscopic examination I found numerous organisms, some simple and irregular in form, some Y-shaped, some twice and three times forked, resembling the rhizobium of the sweet clover to which I gave the name *Rhizobium mutabile* in 1892. Of these few small growths I made a number of test-tube cultures. These cultures developed very slowly, but steadily, producing (upon agar media) a transparent, glistening, slightly elevated, smooth-margined growth of about the tenacity (not stringy) and consistency of syrup. There was no color, odor, or gas formation noticeable. Repeated microscopic examinations showed these cultures to consist of organisms having the morphological characteristics of *R. mutabile* of sweet clover. These morphological characteristics, combined with the very peculiar development of the cultures, led me to assume that I had at last succeeded in obtaining pure cultures of *R. mutabile*. H. B. Carey, working in the same laboratory, succeeded in obtaining numerous similar cultures from *M. alba* tubercles by the fractional culture method. The evidence, though requiring further proof, is sufficient to justify this report. Inoculation experiments on *M. alba* growing in carefully sterilized soil are now in progress, which will be reported upon in the second paper.

Microscopic examination of pure cultures showed the rhizobia in various stages of septation, budding, and branching. The organisms are absolutely non-motile, showing more irregularity in form, size, and branching than in their normal state within the tubercle. They are embedded in a considerable quantity of mucilaginous substance, which does not, however, form a distinctly circumscribed layer about the cell wall. Naturally the study of the mode of multiplication is a comparatively easy task with pure cultures. It multiplies by bi-septation, multi-septation, and by budding and subsequent septation. In comparatively rare instances there is evidence of budding resembling that of

the yeast plant. Growth is usually uniterminal; again it may proceed in either direction or toward all of the extremities of the branching forms, until the maximum size is reached, whereupon it septates. Under favorable conditions, when food supply is adequate, septation proceeds more rapidly and before the maximum size is attained, forming zoöglœa of only partially developed rhizobia. When a fully matured organism septates, the cytoplasm collects into two, more generally three to five, masses, followed by a constriction of the cell-wall between the plasmic masses. Branching forms seem to be due to arrested, prolonged, or incomplete budding, and occur principally in the older, more mature plants, though it may also be noticeable in immature or undeveloped organisms. These peculiarities of form and budding indicate a relationship to Saccharomyces, but there are absolutely no fermentation phenomena in the media.

In the older, larger, and more matured cells are found those small, usually spheroidal, highly refractive bodies to which attention has been called by various investigators, notably Frank. In the culture organisms, as well as in those found in tubercles, these bodies, which vary in number from one to five, usually occupy a peripheral position. They are highly refractive, in that respect resembling spores. In 1894 I described them as modified spores, an opinion not seconded by Frank (a communication in writing). At present I have nothing to add regarding their origin and probable function, though I am still of the opinion that they may be spore-like etiologically, and might be designated sporoids. It seems evident that no true spores are formed, either in the organisms of the tubercles or those grown in media.

Rhizobium mutabile grows in most media, liquid beef broth gelatine, agar, beef broth, whether neutral, slightly acid or slightly alkaline. It seems to grow better upon solid than in liquid media. It grows best, as far as observations have been made, upon solid *M. alba* extract agar. It is not anaerobic, though it may be facultatively so. The fact that the culture is colorless renders the study of deep stab growths difficult,

SCHNEIDER on RHIZOBIUM MUTABILE

especially if the media are not wholly translucent or transparent. In liquid media there is a whitish sediment of rhizobia. There is evidence that growths on solid media become less translucent with age.

The following is a brief summary of results of the present series of experiments:

1. *Rhizobium mutabile* can be isolated and develops in artificial culture media, forming a translucent, colorless, glistening, semi-liquid growth.

2. It develops slowly, requiring from four to six days to produce a perceptible growth.

3. It is essentially aerobic.

4. It multiplies by biseptation, multiseptation, and a modified form of budding.

5. It apparently does not develop true spores.

6. It is devoid of all active motion.

7. It undergoes great changes of form and size, with age and also in different culture media. See figures.

8. Refractive bodies (sporoids) occur in the older organisms, and seem to be characteristic of the species. Their origin and function are as yet undetermined.

9. While of slow growth, it does not seem to be readily destroyed. It may be completely overspread by a foreign germ, but as soon as conditions become unfavorable for the latter the rhizobium is found to be still active and continues to grow and multiply.

NORTHWESTERN UNIVERSITY,
Chicago.

EXPLANATION OF PLATE I.

The illustrations are from pen and ink drawings, made on a uniform scale by means of an Abbé camera lucida. The drawing paper was placed on a level with the base of a Leitz instrument. Magnification by means of a B. and L. 1-12 oil immersion objective and a No. 4 Leitz ocular, draw-tube in.

a, *Rhizobium mutabile* from young root tubercle of *Melilotus alba*.

b, *R. mutabile* grown in agar beef broth.

c, *R. mutabile* grown in beef broth.

d, *R. mutabile* grown in *Melilotus alba* extract solidified by agar.

NOTES ON CERTAIN SPECIES OF ANTENNARIA.

ELIAS NELSON.

CONSIDERABLE attention during recent years has been given to the study of the eastern species of Antennaria. Many species of the middle Atlantic states and of the prairie states of the Mississippi valley have been characterized by Professor E. L. Greene, those of the District of Columbia and vicinity in particular having been the subject of much field study by the same author. Mr. M. L. Fernald has published a synopsis of the New England species, supplemented by subsequent papers containing notes and a key. Through the field and herbarium studies of Mr. Fernald, and the notes and observations of various collectors, the species of the New England states are perhaps better known than those of any other region of equal area in North America. The most recent synopsis of the eastern species is that which has appeared in Dr. Britton's *Manual*. Thanks to the efforts of many collectors, we are constantly becoming better acquainted with these plants, but much remains to be learned even concerning the eastern species.

A revival of interest in any long neglected group of plants, is generally attended with much describing of species, resulting in many new names, some of which must sooner or later be relegated to synonomy. It is not at all surprising, therefore, to find that several of the species now generally accepted have received two or more names during the recent study of this genus. What in many instances appeared to be very distinct, on further examination in the light of more material often proves to be less deserving of the specific or perhaps sub-specific recognition at first accorded it. A fair representation of a species by specimens from different localities in its range is necessary for an adequate knowledge of the plant. The variations, relationship, and distribution of each species needs to be worked out, and as

regards our eastern Antennarias this remains to be done for most of them.

The plantain-leaved species are very polymorphous and almost indistinguishable. It would not be at all difficult in any large collection to spread out a series of specimens exhibiting a gradation of *A. neglecta* through *A. petaloidea* and *A. ambigens* into *A. Parlinii*. In spite of the frequent intergradations we do recognize as tolerably well marked some categories of forms to which it seems proper as well as desirable to assign binomial names. Though authors will to some extent differ in judgment as to the validity of certain species, it is gratifying to note that different investigators in this group in several instances have reached the same conclusions.

In the segregates of *A. plantaginifolia*, *A. dioica*, and *A. alpina* of earlier American authors, the general habit and stature of the plant, the outline and size of the leaves, the character and permanency of the pubescence, and the height of the involucres are of most value for specific diagnoses. The outline of the bracts of the pistillate involucres, especially as regards the bluntness or acuteness of their tips, are of minor importance in distinguishing species. In most of the eastern as well as of the western Antennarias I have found that the tips of the involucral bracts (pistillate) vary from obtuse to acute or acuminate. The outline of the bracts has quite generally been given in recent descriptions, and the bluntness or acuteness of their tips has in many instances been taken as one of the distinctive characters of certain species and sub-species. The amount of thickening or dilation of the pappus bristles of the staminate flowers is also found to be subject to considerable variation in the same species.

It is a well established fact that parthenogenesis occurs in the real *Antennaria alpina*. While there is at present no evidence to show that any North American species are propagated parthenogenetically, it perhaps would not be at all surprising to find that it does take place in some of them. We at least know that good seeds may be produced. Mr. Theo Holm, of Brookland, D. C., assures me that he has observed in that vicinity an abun-

dance of seedlings, but which species they represented could not be determined. They were found, however, near patches in which *A. Parlinii* (*A. arnoglossa*), *A. plantaginifolia*, and *A. neglecta* were growing. In Antennaria, as well as in the related genera Gnaphalium and Anaphalis, the plants may be polygamo-dioecious. *A. plantaginifolia* (*A. decipiens* Greene), however, is the only species in which I have observed perfect flowers.

In consequence of my distribution of North American Antennarias I have received many collections from various parts of the United States and Canada, thus giving me an opportunity to study among others the species of the eastern United States. The material in the U. S. National Herbarium has been at my disposal, and through the courtesy of Professor E. L. Greene it has been my privilege to examine the types of his species. I am under great obligations to Mr. M. L. Fernald for communications of specimens and other favors. The facts which have been brought out in the course of my study of the eastern species and the opinions I have been constrained to entertain are set forth in the following notes, which I hope will not be without interest to the students of this genus.

ANTENNARIA LABRADORICA Nutt. Trans. Am. Phil. Soc. 7:406. 1841.— A very good species, originally described from Labrador specimens. It is in part the *A. alpina* of Britton's *Manual*. There can be no doubt as to its distinctness from *A. alpina*. Nuttall himself says of it: "at first glance resembling *A. alpina*, but more nearly allied to *A. plantaginea*." Its affinities are with *A. canadensis* and *A. neodioica*, the brownish involucres suggesting *A. alpina*. I have examined an undoubted specimen of this species deposited in the herbarium of the Geological Survey of Canada (sheet no. 14363). Since Professor Greene, who has seen the same material, gives a brief characterization of the species,[1] I will here only record some measurements taken of some parts of the plants on this sheet. Basal leaves 1–2^{cm} long; lowest pedicel of the inflorescence 3.5^{cm} long; involucres 6–7^{mm} high.

[1] Pittonia 3:285. 1897.

ANTENNARIA NEODIOICA Greene, Pittonia **3**: 184. 1897.—*A. neodioica attenuata* Fernald, Proc. Bost. Soc. Nat. Hist. **28**: 245. 1898. *A. rupicola* Fernald, Rhodora **1**: 74. 1899. *A. alsinoides* Greene, Pittonia **4**: 83. 1899.—This species was described from specimens secured near Stroudsburg and Bushkill in the extreme eastern part of Pennsylvania. Typically it has involucres whose outer bracts are obtuse and the inner acute. True *A. neodioica* is much less common than the forms with narrow, attenuate involucral bracts. The staminate plants are certainly very rare, being unknown both to Mr. Fernald and myself. Professor Greene, however, seems to have had some staminate plants when drawing up the original description.

Taken in its entirety, this species is readily separated from any Antennaria to be found in eastern North America. It is quite variable, and some of its forms have received sub-specific or even specific names. Dr. Britton[2] considers all the forms of this particular category as representing only one species. In this I think he is entirely right. I had myself, independently, reached the conclusion that *A. neodioica attenuata* and *A. alsinoides* are the same, and am now of the opinion that the form to which these two names were applied cannot consistently be accorded even sub-specific rank.

An examination of a series of specimens from localities ranging from Ontario and the New England states to Maryland shows that the species varies chiefly as follows: basal leaves from relatively narrow with oblanceolate expanded portion and then not clearly differentiated into blade and petiole, to rather broad, the expanded portion obovate with a more distinct petiolar base; inflorescence from somewhat paniculate to subcorymbose, either closely congested or tolerably open; bracts from much acuminate to more or less obtuse, scarious or petaloid, rarely lemon-tinged. Were any two or more of these variations always associated, there would here be some justification in recognizing sub-species. Professor Greene states that his *A. alsinoides* as compared with the typical *A. neodioica* has its heads

[2] Science, n. s. **13**: 587. 1901.

on shorter pedicels, and that its leaves are more "clearly differentiated into blade and petiole," the expanded portion of the leaves being obovate. The congested character of an inflorescence is found to be by no means always accompanied by relatively broad leaves, for some Ontario specimens examined by me have an inflorescence answering to Professor Green's description, but the expanded portion of the leaf is oblanceolate. The stolons are said to be equally leafy throughout, but that is quite often the case in typical *A. neodioica*. Mr. Fernald assigns to his *A. neodioica attenuata* no other distinctive characteristic than that exhibited by its involucral bracts. It does not seem well to make sub-species on single characters, especially of a species with such freely intergrading forms. The character of attenuate bracts is accompanied either by relatively narrow or rather broad leaves, and either by a close or tolerably open inflorescence. Mr. Fernald has characterized another sub-species, viz., *A. neodioica grandis*, of which I have seen no specimens. *A. rupicola* is merely a dwarfish form of *A. neodioica*, with lemon-tinged involucral bracts and basal leaves slightly narrower than is ordinarily the case in this species.

ANTENNARIA PETALOIDEA Fernald, Rhodora **1**: 73. 1899.—*A. neodioica petaloidea* Fernald, Proc. Bost. Soc. Nat. Hist. **28**: 245. Je 1898. *A. neglecta subcorymbosa* Fernald, *l. c.*, 246. *A. Farwellii* Greene, Pittonia **3**: 347. S 1898. *A. petaloidea scariosa* Fernald, Rhodora, *l. c.* *A. petaloidea modesta* Elias Nelson, Proc. U. S. Nat. Mus. **23**: 710. 1901.—In this species we have a connecting link between the unusually well marked *A. neglecta* and *A. ambigens*. Though grading into *A. neglecta* it may be distinguished readily from that by its corymbosely cymose inflorescence and generally broader leaves. The heads are as a rule more numerous than in *A. neglecta*. In that species, as noted by Mr. Fernald, the staminate plant is quite as common as the pistillate, while in this it is very rare. As in *A. neglecta*, the thin tomentum of the upper surface of the leaves is either persistent or deciduous. In outline the leaves vary from spatulate or oblanceolate to obovate-cuneate, and in width from 7 to 17^{mm}.

The stolons, though generally like those of *A. neglecta*, are often more leafy, and then resemble those of *A. ambigens*. *A. petaloidea*, when constituted as a species by Mr. Fernald, was known to him only from northern New England. I have it, however, from two localities in Ontario, and Mr. C. K. Dodge has collected it repeatedly in St. Clair co., Mich. Undoubted specimens of this species have also been secured by Professor De Alton Saunders in the Black hills of South Dakota. This collection contains both pistillate and staminate plants. The latter are 8–13^{cm} high, with two to four heads to the cluster, the bracts with oval to oblong, obtuse tips, and the pappus bristles with moderately and uniformly thickened upper portions, or occasionally very slightly dilated at summit.

I have examined the type of *A. Farwellii*, and find that it is nothing else than *A. petaloidea* Fernald. What Mr. Fernald[3] and Dr. Britton[4] have supposed to be *A. Farwellii* is not that species, but a much larger-leaved plant closely allied to *A. ambigens*. The basal leaves in the type are lightly tomentose above, indistinctly 3-nerved beneath, only 3–4^{cm} long, and not exceeding 13^{mm} in width.

ANTENNARIA PARLINII Fernald, Gard. & For. **10**: 284. 1897.— *A. arnoglossa* Greene, Pittonia **3**: 318. 1898. *A. Parlinii arnoglossa* (Greene) Fernald, Proc. Bost. Soc. Nat. Hist. **28**: 243. 1898.— The typical form of this species is a New England plant with leaves green and glabrous above from the first, with stems beset with purplish ciliate hairs and with large involucres of narrow acuminate inner bracts. There are some deviations from this type even in the New England states. The ciliate hairs are at times absent, and the basal leaves often slightly arachnoid above. Some Illinois specimens examined by me are also somewhat arachnoid on the upper surfaces of the leaves, and very few ciliate hairs are present. In plants from Washington, D. C., and vicinity the ciliate hairs are present in some, absent in others, the leaves either wholly glabrous above or nearly so and the involucral bracts either broad and obtuse or rather narrow. It

[3] Rhodora **1**: 153. 1899. [4] Manual, 976.

will be seen from the above account of its forms that as to involucral bracts, glandulosity, and presence of ciliate hairs it presents the same variations as *A. ambigens*. As to stature, size of leaves and involucres, and general habit it resembles that species very closely and indeed it grades into it. Although there is no sharp line of demarcation between these two species, yet it seems well to let the two names *A. ambigens* and *A. Parlinii* stand for the two categories of forms, those with permanently tomentose upper surfaces of the leaves falling into the former, and those with leaves smooth above or nearly so into the latter. From *A. plantaginifolia* the species is quite readily separated, and though the chief distinction is that of size the difference is constant, and I think no one who once has formed a mental picture of the two species would have any difficulty in distinguishing them.

ANTENNARIA PROPINQUA Greene, Pittonia **4**: 83. 1899.—Originally described from staminate specimens only, collected at Harper's ferry, West Virginia, but now also known to me through plants secured by G. B. Ashcraft at Berea, Ohio. This collection contains both staminate and pistillate specimens. Even the pistillate plants are rather low, only 16 ^{cm} high; the heads few and closely congested, and the involucres 8 ^{mm} high. The herbaceous portion of the involucral bracts is livid green and glandular. The inner bracts of the pistillate involucres are narrow and acuminate, while the outer are somewhat broader, their tips oblong, lanceolate, or oblong-linear, acute or obtusish. The pappus bristles in the staminate flowers are only slightly narrower at the tips than those observed in some specimens of *A. Parlinii*. When more specimens of *A. propinqua* are at hand, we shall be able to judge better of its claims to specific rank.

ANTENNARIA BRAINERDII Fernald, Rhodora **1**: 153. 1899.—It is doubtful whether this can be maintained as a distinct species. As exemplified by Mr. W. W. Eggleston's specimens of 1899 and President Brainerd's of 1900, it is certainly very closely allied to *A. Parlinii* on the one hand and to *A. ambigens* on the other. In both of those species, as we have already noted, the presence or absence of ciliate hairs is a matter of much variation, and in

both the basal leaves are at times relatively as broad as those of *A. Brainerdii*.

ANTENNARIA AMBIGENS (Greene) Fernald, Rhodora **1**: 150. 1899.—*A. arnoglossa ambigens* Greene, Pittonia **3**: 320. 1898. *A. Parlinii ambigens* (Greene) Fernald, Proc. Bost. Soc. Nat. Hist. **28**: 244. 1898. *A. fallax* Greene, Pittonia **3**: 321. 1898.—This is the commonest of the eastern species of Antennaria which have large heads and ample, plantain-like basal leaves. It ranges from Minnesota, Ontario, and Maine to Kansas, Mississippi, and Virginia. As many other American species, it is quite variable. It is nearly always more or less glandular, quite as often so in the acuminate-bracted forms as in the typical one. Ciliate hairs may be found about the inflorescence, on the stems, and on the margins and surfaces of the leaves. These hairs are usually purple, but when occurring on the surfaces of the leaves are colorless. The upper surfaces of the basal leaves are permanently arachnoid or tomentose above, and the tomentum of their lower surfaces is generally persistent. Often, however, it forms a crustaceous coating which occasionally is deciduous in flakes. The involucral bracts of the pistillate plants may be either narrow and attenuate or broader and petaloid. Often they are purplish as in *A. Parlinii*. There is some variation in the stature of the plant, the leafiness of the stems, and the character of the inflorescence, but these variations fail to furnish any diagnostic characters. The staminate plant is somewhat lower and its involucral bracts have ovate or oblong, obtuse, petaloid tips. The pappus bristles are either clavellate or more or less dilated and then bluntly toothed or somewhat lacerate, the filamentous portion serrulate upwards.

The type specimens of *A. arnoglossa ambigens* were collected near Brookland, D. C., and Professor Greene informs me that he has found but one patch of it and that situated in a field of his *A. fallax*. These specimens are slightly glandular and the tips of the outer involucral bracts are oblong and obtuse, those of the inner acuminate. On one of the sheets the plants have some purple hairs about the inflorescence.

The type material of *A. fallax* was collected in the same locality as that of *A. arnoglossa ambigens*. There are six sheets labeled *A. fallax* in the herbarium of Professor Greene. On three of the sheets the plants are without ciliate hairs, while on the other specimens these are present. Only two of the four specimens of pistillate plants have attenuate inner bracts, and in only one of these are they setaceously pointed. One of these specimens with inner attenuate bracts has some purple hairs about the inflorescence.

There is thus a very evident gradation of *A. arnoglossa ambigens* into *A. fallax*, even in the original material. A careful study of a larger series of specimens shows that the two cannot be separated, being simply forms of one species. I have recently learned through a communication from Mr. Fernald that further observation in the field has led him to the same conclusion, and Dr. Britton[5] also is inclined toward this belief.

ANTENNARIA PLANTAGINIFOLIA (L.) Rich. in Hook. Fl. Bor. Am. **1**: 330. 1837.—*Gnaphalium plantaginifolium* L. Sp. Pl. 850. 1753. *G. plantaginea* L. Syst. Veg. Ed. 12. **2**: 545. 1767. *A. plantaginea* (L.) R. Br., Trans. Linn. Soc. **12**: 123. 1818. *A. decipiens* Greene, Pittonia **3**: 278. 1898.—*A. nemoralis* Greene, Pittonia **4**: 41. 1899. This is the low, plantain-leaved species, having small heads and foliage persistently arachnoid on the upper surface. It is closely allied to *A. ambigens* and grades into it. It is a comparatively glandless plant, the flowering stems and the leaves being rarely at all glandular, and in no specimens have I detected any ciliate hairs. The basal leaves vary from round obovate to ovate or narrowly elliptic, and the petiole is often much elongated, especially in the forms with narrower leaves. The bracts of the pistillate involucres are generally petaloid and obtuse or obtusish, but not infrequently somewhat scarious and acute or acuminate in the inner. In the staminate involucres the whitish tips are oval, ovate, or oblong, and vary in different plants as to size and number. The pappus bristles in the staminate flowers though generally very narrow

[5] Manual, p. 796.

and serrulate are at times somewhat dilated toward their apices.

I am unable to separate *A. nemoralis* Greene from this species. It is of the same size and has the same foliage characteristics as *A. plantaginifolia*. Mr. Albert Ruth has sent me some material secured by him in the same grove in which was collected the type of *A. nemoralis*. The leaves in these plants vary from ovate and elliptic to round ovate, and the arachnoid pubescence is persistent on the upper surface. There were two pistillate plants in Mr. Ruth's collection, and these have the narrow involucral bracts characteristic of *A. plantaginifolia*.

Hermaphrodite flowers apparently are not infrequent in this species. Plants with some flowers containing well developed stamens and pistils and plump akenes have been detected in three different collections. These specimens are respectively from Biltmore, North Carolina, Takoma park, D. C. (*E. N. Wilcox*, 1901), and Knoxville, Tennessee (*Albert Ruth*, 1901). They are in each case accompanied by sterile plants. They are readily distinguished from both the strictly pistillate and the staminate individuals by their involucral bracts, which are much broader than in the former, but not as broad as in the latter; or, to be more definite, their obtuse, white tips are from oblong-linear to oblong. The pappus-bristles are coarser than those of the pistillate flowers, slightly thicker toward their apices and somewhat serrulate. In their general appearance the heads of the individuals having some perfect flowers resemble those which are strictly pistillate, and indeed I at first mistook them for pistillate plants.

ANTENNARIA OCCIDENTALIS Greene, Pittonia **3**: 322. 1898.— The plant which I at present tentatively refer to *A. occidentalis* is the *A. Farwellii* of Mr. Fernald and Dr. Britton. It appears to be quite distinct, and is known to me through specimens from New York, Vermont, Ontario, Michigan, and Wisconsin. As to the involucres and the outline of the basal leaves, it agrees so well with Professor Greene's description of *A. occidentalis* that I refrain from assigning it a new name until satisfied that it is not that species.

ANTENNARIA ARGENTEA **aberrans,** subsp. nov.—Like the species, but inflorescence racemosely paniculate.—Type in the U. S. National Herbarium, collected by M. E. Jones on Mt. Shasta in California, alt. 5,000 ft., June 18, 1897. There are only pistillate plants on the sheet, and these are about 15^{cm} high, and have oblanceolate, acute radical leaves 3–4^{cm} long and 6–7^{mm} wide.

UNIVERSITY OF WYOMING,
Laramie.

A SURVEY OF THE HURON RIVER VALLEY.

I. THE ECOLOGY OF A GLACIAL LAKE.

HOWARD S. REED.

(WITH FOUR FIGURES)

I. INTRODUCTION.

IN the vicinity of Ann Arbor, Mich., there are a number of glacial lakes and ponds which at no very distant day must disappear if the processes now in operation continue. At present they exhibit conditions of such interest that it has seemed very desirable to preserve as complete a record as possible of their extent, physical characters, and biological relations as they exist today. The work here reported was carried on at the largest of the so-called "Sister lakes" west of Ann Arbor.[1] It was undertaken at the suggestion of Professor V. M. Spalding, of the University of Michigan, under whose direction the botanical survey of which it forms a part is now in progress. It has been the purpose of the writer to give an exact representation of existing facts and conditions, and to study in a somewhat quantitative manner the relative value of the several ecological processes at work; necessarily some matters of theoretical interest are discussed.

The study of a glacial lake is of peculiar interest to students of ecology. The physiography of the country in which such lakes occur was entirely rejuvenated by the glacial action, and the physiographic processes taking place now are precisely those rapid developments characteristic of new land areas. Adaptations to past conditions still remain, but with them are striking and interesting adaptations to present changing conditions. The general change has been from semi-arctic and hydrophytic to temperate and mesophytic conditions. At the same time, there

[1] A preliminary report of this work was published in the Proceedings of the Michigan Academy of Science for 1901.

has been a continuous reaction of plant life upon environment; the advancing zones leave soils behind them different from those they found. Sphagnum swamps and peat bogs, into which the lakes now under consideration are changing, are the last stages in the life history of glacial lakes.

The plant life of the small glacial lakes characteristic of southern Michigan differs distinctly from most other hydrophytic societies. It is predominantly xerophil, while that of a brook or river is predominantly hydrophil in character.[2] It differs from the flora of such lakes as have been studied by MacMillan[3] and Pieters[4] in not being influenced by waves, currents, spray, etc.

II. GEOLOGICAL HISTORY.

The lake selected for study is a "kettle-hole" in the terminal moraine which formed part of the northwestern shore of ancient Lake Maumee. It is mainly fed by springs issuing from the bottom and around the shores, though a small rivulet entering from the southeast contributes some surface water during about half the year. The lake probably came into existence at the close of the second advance of the ice sheet, and at that time it was considerably larger than at present, due to the drainage from the melting ice. For some time following the formation of the lake it was apparently subject to sudden changes in size and outline due to rapid fluctuations in the water supply. There are two similar lakes within a mile to the eastward, with which it formerly may have been continuous; at present the surface of the water is five inches lower than in either of the other two lakes.

The original lake must have been from sixty to eighty feet deep in its deeper parts, and the surplus waters were discharged through an outlet to the southwest which emptied into the Huron river. The eastern shore was fifteen or twenty rods farther east than at present; while from the southeast a wide

[2] COWLES, H. C., BOT. GAZ. 31: 145. 1901.

[3] MACMILLAN, C., Minnesota Botanical Studies, 50.

[4] PIETERS, A. J., U. S. Fish Com. Bull., pp. 57–79. 1901.

cape extended into the lake, which now appears as a hill near its southeastern corner. West and southwest of this cape the water's edge was about twenty rods back of its present position, and the former western margin was approximately parallel to the present one, but four or five rods farther inland. A shallow bay extended off toward the northwest, which is still traceable by the extension of plant zones in that direction. On account of the steepness of the northern shore, the water on that side extended only a few rods beyond its present limit.

This former extension of the lake has had a marked influence upon the present plant societies. While it prevailed it necessarily drowned out all terrestrial forms; then as the water level slowly fell the aquatic and semi-aquatic species had the first chance to get a foothold and become established upon the land which was thus gradually uncovered. This was especially the case on the east, west, and southwest shores of the lake, where, on account of the gentle slope of the bottom, there was always a wide strip of shallow water in which aquatics and semi-aquatics could get a strong foothold and become established long before it was suitable for the occupation of terrestrial forms. Even today the zone of willows is destitute of any considerable number of distinctly terrestrial plants.

At a certain stage in the recent geological history of the region, as the water level fell, the large lake was divided into two, the present lake and a similar, smaller one ten rods south of it which has all but disappeared. The fate of this smaller lake throws some light on the history of the present lake, as will be shown later.

III. PRESENT CONDITIONS.

1. PHYSIOGRAPHIC RELATIONS.— As it now exists, the extreme east and west diameter of the lake is a little more than thirteen hundred feet long, the extreme north and south diameter is seven hundred feet. Between the water's edge and the higher ground which formerly constituted the shores is a swampy border varying in width from ten feet to twenty rods. The thick growth of vegetation in this border has nearly clogged the

sluggish outlet at the southwestern corner of the lake. The border swamp is interrupted on the south side of the lake by the former delta of the brook entering at that place. The delta rises several feet above the level of the surrounding shore and differs from it very markedly in vegetation (*fig. 1*).

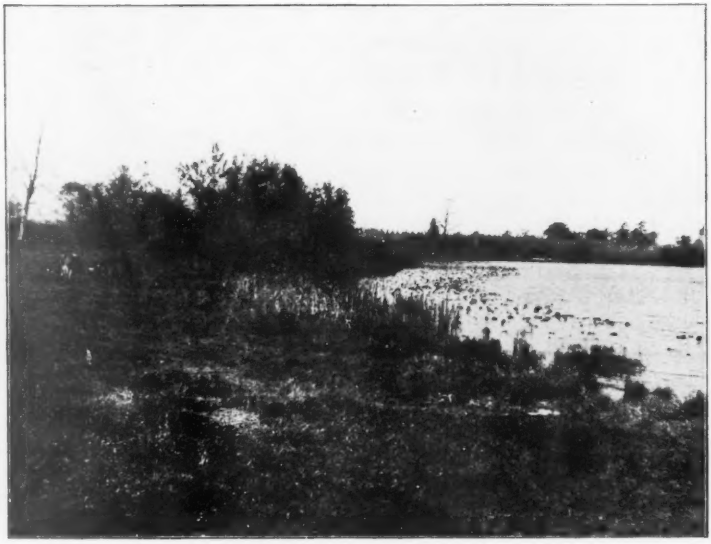


FIG. 1.—South shore of the lake, part of the former delta plain in the foreground.

The lake basin proper is surrounded by a shallow marginal rim varying from forty to seventy-five feet in width and descending from the water's edge at one side to eighteen or twenty feet below the surface at the other. This marginal rim owes its existence primarily to organic factors which are still at work modifying and extending it. The soil for several feet in depth is largely composed of organic material which presents the usual successive gradations from vegetable detritus to muck and peat. The bottom descends very rapidly from this rim to form the main central basin, which averages more than fifty feet in

depth. The soil of the central basin is almost pure loess-like clay mixed with a little fine vegetable detritus which settles from the water of the lake; this area, so far as numerous dredgings show, is entirely barren of vegetable life of any kind.

The water of the lake enters chiefly by underground channels and from springs at the bases of the gravel hills surrounding the lake. During the greater part of the year the supply is just about equal to the loss by evaporation, and except during seasons of maximum precipitation there is very little water passing into the outlet. The water dissolves and holds in solution so much organic substance from the decaying vegetation in the lake that a very perceptible taste is imparted to it. The fine detritus held in suspension together with the dissolved substance renders the water brownish, making it impossible to distinguish objects more than six feet below the surface. The opacity of the water is an important factor in determining the distribution of plants. Obviously there are no perceptible currents in so small a lake.

2. THE PLANT SOCIETIES.—The deep central portion of the lake does not, so far as could be ascertained by dredging, support any plant life; this cannot be due to the soil, for in other lakes the same soil is covered with Chara and Potamogeton, but is undoubtedly due to the feeble intensity of light at depths greater than twenty feet.

The plants at the lake are grouped in five fairly well defined concentric zones, occupying all the suitable lake bottom less than twenty feet under water, and all the land surrounding the lake which feels the influence of the presence of the water. Beginning with the innermost, they are:

(*a*) *A zone of Potamogeton*, which extends in water from eighteen feet to six feet in depth completely around the lake just shoreward of the central depression, and forms a zone averaging thirty feet in width. This zone is composed almost exclusively of *Potamogeton zosteraefolius* Schum., which grows very luxuriantly, forming a dense tangled mat. The only other plant found in this zone is *P. lucens* L.

(*b*) *A zone of Nuphar*, extending nearly around the lake, occupying the territory between the preceding zone and the water's edge. This forms a zone between thirty and seventy feet in width, whose lakeward side is about six feet below the surface of the water, while the shoreward side is limited by the

FIG. 2.—North shore of the lake; Nuphar, Carex, and Salix zones; the shrubs in the background are mostly *Populus tremuloides*.

water's edge. The most abundant and characteristic plant in this zone is *Nuphar advena* Ait. f. Its rapid growth and hardiness make it a successful competitor in the struggle among aquatic plants, and it is admirably adapted to the requirements of an advancing plant society, growing as vigorously in water six feet deep as in water six inches deep (*fig. 4*). Associated with it are *Potamogeton natans* L., *P. lucens* L., *Chara coronata* Ziz., *Dulichium spathaceum* Pers., and *Typha latifolia* L.

In places where for any reason Nuphar does not grow or grows only sparingly, *Potamogeton zosteraefolius* comes in; where Nuphar grows well Potamogeton is not found.

(*c*) *A zone of Carex and Sphagnum*, whose surface is practically at water level, extends landward from the water's edge from six to twenty-five feet. This is an exceedingly well defined zone (*fig. 2*), and lying so close to the water level it is necessarily saturated with water, and the tough mat of sedges is in many places little better than a floating morass. The soil underlying it is composed entirely of black muck and decaying vegetable matter. The most abundant plants are *Carex filiformis* L., *Sphagnum*, and *Potentilla palustris* Scop.

(*d*) *A zone of Salix and Populus*, varying from ten to forty feet wide, extends entirely around the lake and stands from three to twenty-four inches above the preceding zone. The soil of this zone is almost entirely of vegetable origin; in different parts and at different seasons it contains varying amounts of water. It never becomes mesophytic in character, and is often hydrophytic. A very few vigorous mesophytic species occur with the characteristic plants of this zone, but they usually show changes of habit to correspond to their environment. The characteristic plants of this zone are *Salix alba* L., var. *vitellina* Koch, *S. lucida* Muhl., *S. myrtilloides* L., *Populus tremuloides* Michx., and *Ulmus americana* L.

(*e*) *A zone of Gramineae and Compositae* lies just outside the last zone, and is from six to thirty inches above it. In this zone there are adaptations to past, rather than to present conditions. It is the transition zone in which mesophytic species begin to mix with hydrophytes, its landward border merges gradually into the vegetation of the surrounding country. The greatest admixture of terrestrial plants occurs on the north and southeast shores, where the struggle between plants has been most severe for some time. While it is difficult to designate distinctly characteristic plants for this zone, the following are among the most constantly recurring species: *Spiraea salicifolia* L., *Monarda fistulosa* L., *Rumex obtusifolius* L., *Eupatorium perfoliatum* L., *Salix discolor* Muhl., *Juncus canadensis* J. Gray, *Epilobium coloratum* Muhl., *Hypericum canadense* L., *Nepeta cataria* L., *Sambucus canadensis* L., *Acer rubrum* L., *Gentiana Andrewsii* Griseb., *Bidens bipinnata* L.

Careful collections were made during the entire growing season, and included practically all the species occurring at the lake. They represent forty-three families; 5 per cent. of them are natives of arctic regions; 65 per cent. are natives of North America.

3. INTERZONAL RELATIONS.—A study of the different zones and their relations to one another shows that their positions are not permanent, but that they are slowly encroaching upon the lake, and as a result are filling it with the soil they produce. Each society of plants is a more or less active soil-forming agency, and accordingly as the vegetation progressively changes the advancing zones leave a different soil from the one they found. The vigorous growth of *Potamogeton zosteraefolius* adds by its death and decay a very small amount of humus to the fine clay soil upon which it grows. Nuphar is a much more active soil-forming agent; its strong leaves and petioles projecting above the surface of the water (*fig. 2*) catch and hold most of the twigs, plants, and leaves which are blown into the margin of the lake, until they become water-soaked and sink. The débris resulting from the decay of the water lilies, added to that which they have captured, all goes to building up the bottom of the lake. On account of the limitation of Chara to the Nuphar zone, and the consequent absence of any extensive beds, it is not an active soil-forming agent by the production of marl, as it is in some of the glacial lakes of Michigan.[5]

In the intense competition among the plants of this crowded zone there is a constant tendency to move out in the direction of least resistance. Limited as it is on the landward side by less favorable conditions, the zone must make its advance, if it makes any, into deeper water, *i. e.*, into the Potamogeton zone, which it appears to do just in so far as Nuphar is able to adapt itself to the greater depth of water, or as the Potamogeton builds up the bottom. At the other side of this zone there is a tension line between the water lilies and the sedges. Whenever in any place the bottom is not more than three or four inches below the sur-

[5] DAVIS C. A., Jour. Geol. **8**: 485 and 498.

face of the water, the sedges begin to move out and occupy the territory thus prepared for them. Perhaps at first they send out a few skirmishers that occupy the top of some muskrat's mound, but generally they advance with an unbroken line and cover the soft muck with a tough quaking mat of vegetation. No advance

FIG. 3.—Gravelly shore at southeastern corner of the lake; absence of Nuphar and Carices results in a permanent shore-line.

of any extent is ever made without a fairly firm soil to grow upon. *Scirpus lacustris* is one of the foremost plants in the advance. As the Carex zone crowds upon the Nuphar zone, so in turn it is itself crowded upon by the Salix zone. *Salix rostrata* and *Betula pumila* are among the foremost of the plants encroaching upon the Carices. On gravelly banks and in localities where conditions are unfavorable for the growth of Nuphar, this process of filling does not occur, because the preliminary process of filling by decay cannot take place. The result is that the shore

line in such places is quite well marked and permanent (*fig. 3*).

A few rods south of the lake is the site of the "dead lake" mentioned above, a description of which may, as suggested, throw some light upon the life history of the present lake. At present the only indication of the former pond is an elliptical depression surrounded by representatives of the Gramineae and Compositae zone, but in the spring of the year the depression is filled with water to a depth of about two feet, in which several species of Polygonum grow vigorously. Before July the water has all disappeared from this basin and for the remainder of the year it is dry. In the center of the depression there is a group of sedges and ferns which is surrounded by a wide belt of willows; outside of these again is a zone of grass and terrestrial plants. The whole state of affairs suggests that this has been the site of a pond which has been steadily encroached upon by the zones of vegetation in the manner previously described, until now the pond is practically obliterated. The sedges have exterminated the water plants and now the willows have all but exterminated the sedges.

This pond, originating from the primitive lake, must have been essentially the same in character as the lake under consideration; it seems reasonable therefore to conclude that the pond represents an advanced stage yet to be realized in the life history of the lake.

IV. ECOLOGICAL FACTORS.

The plant societies afford unmistakable evidence of the influence of the glacial epochs. The flora of glacial lakes may be compared to boreal islands composed of plants forced southward by the advance of the ice sheet. The sphagnums and sedges flourish best in those conditions which best reproduce boreal environment, and so long as any plant society remains which is distinctly lacustral it will undoubtedly show traces of its boreal origin.

Agencies now at work may be considered under four groups of factors, viz.: hydrodynamic, edaphic, atmospheric, and biotic.[6]

[6] WHITFORD, H. N., BOT. GAZ. 31: 291. 1901.

(*a*) *Hydrodynamic factors*, referable to the action or presence of water. Small waves are created in the lake by high winds which would eat away the light soil composing the shores but for the fact that such shores are everywhere protected from wave action by a border of water lilies (*fig. 2*). Even in winter this action is prevented because the dead leaves remain *in situ* until the next year. The current of the brook entering from the southeast sweeps away or covers with gravel the accumulations of detritus at that point; as a result, Nuphar and its associates are not found there (*fig. 3*). Aside from this local influence hydrodynamic factors at the present time are so limited in their action that they may be disregarded.

(*b*) *Edaphic factors*, depending upon the nature of the soil. The humus in the soil formed by the decayed vegetable substances renders it very favorable for plants of the Nuphar, Typha, and Carex types. The presence of water saturated with organic matter in solution plainly influences the character of the vegetation. If Schimper's view[7] of the effect of humic acid be correct, the explanation of the xerophytic character of some of these swamp plants is that the soil is practically undrained and water with which it is saturated is rich in organic acids.

A microscopic examination of the soil from the deep basin of the lake shows that it is almost entirely composed of finely comminuted, bluish-gray clay with a very few particles of organic débris. The soil from the Nuphar zone is largely composed of fragments of epidermal tissue, moss-stems, diatom shells, bast fibers, grains of sand, and crystals of calcium carbonate from Chara. Chemical analysis shows that nitrates and nitrites are not present in the soil, while phosphates are more abundant.

That portion of the lake bottom which is covered with soil of a calcareous or arenaceous nature does not seem favorable to the growth of the characteristic plants of the lake; the only ones which grow upon such soil are *Potamogeton zosteraefolius* and a few blue-green algae. Evidently lime-containing soils are as

[7] SCHIMPER, A. F. W., Pflanzengeographie, p. 18.

unfavorable for some other swamp plants as they are for sphagnums.[8]

The plants might be classified as to edaphic relations in the following manner: *argillaceous soil*, unattached microscopic plants, diatoms, etc.;[9] *calcareous and arenaceous soils*, Potamogeton

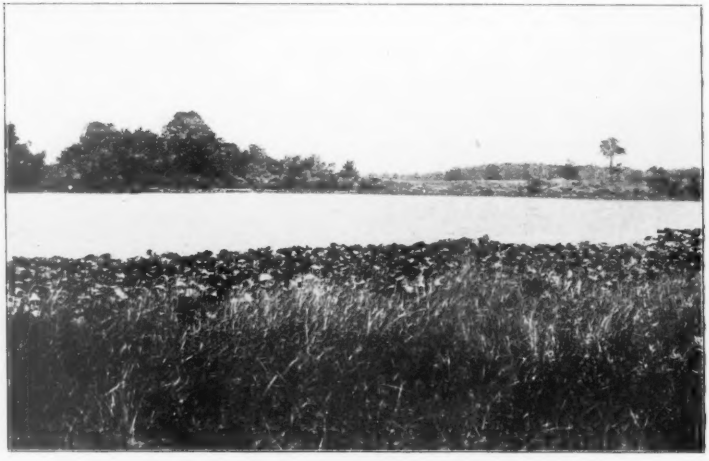


FIG. 4.—Carex and Nuphar zones, showing the massing of these plants; July 1.

zosteraefolius, Blue-green algae (rare), Scirpus lacustris, Potamogeton natans, Chara coronata, Equisetum, Panicum Crus-galli; *carbonaceous soils*, Nuphar, Typha, and Carex societies, Salices, Sphagnum, Populus.

(*c*) *Atmospheric factors.*—The most important of these is light, because, as I believe, it is this which, aside from food supply, chiefly governs the encroachment of one zone upon another. A moment's consideration will show that the plants struggling for light will have better illumination on the side of the center of the lake than on the side toward the land. Take, for example, the Carex zone (*fig. 4*). The young Carex and Sphagnum

[8] GANONG, W. F., Trans. Roy. Soc. Canada, 3: 131. 1897.

[9] Under better conditions of light, Chara and Potamogeton would doubtless occur.

plants on the landward side of the zone are overshadowed by the taller Salix and Betula plants, while on the other side there is almost nothing to diminish the supply of light. In general the plants of a zone which is successful in displacing another zone have a greater capacity for the absorption of light than those plants which they displace. One of the chief advantages of Nuphar over Potamogeton is to be found in the fact that it sends its leaves up to the surface of the water where they receive the full intensity of the light instead of the diminished amount which is able to penetrate the cloudy water to the submersed species. The lack of light caused by the cloudiness of the water seems to be the only reason for the absence of vegetation from the central deep portion of the lake.

The amount of heat which the different aquatic plants receive also varies with their distance from the surface of the water; however, they seem perfectly able to adapt themselves to these differences.

(*d*) *Biotic factors.*— Fully as important as any of the fore going factors are the conditions imposed upon plants by the presence of other plants or animals; conditions to which they must adapt themselves if they survive. The competition between different societies of plants is mainly directed toward obtaining light and food. The former has been briefly considered; there are certain biological characteristics which are favorable for obtaining the other. Perennial plants are the most successful in the interzonal struggle; they are usually adapted to xerophytic conditions by their rhizomes, waxed epidermis, and hairy surfaces. There are also special advantages in their manner of reproduction. The possession of underground rootstocks is one of the best adaptations to enable a plant to hold its own against its competitors; young plants are thus sustained by the parent plant until they are fully capable of maintaining an independent existence, and prompt occupation of a given area is easier. The advantage of the willow lies in the great number of seeds produced and the good means of disseminating them. The advantage of the sedges is in the thick mat of

rhizomes and the dense covering of long grassy leaves; the seeds are heavy and tend to fall on the territory already occupied by the parent plant.

Tension lines are the strongest where the environment is most equally favorable for each of two different societies; *e. g.*, the boundary between the Nuphar and Carex zones is the scene of a severe struggle because the conditions are almost equally suitable for both societies, but where the Nuphar zone borders immediately upon the Salix zone the tension line is weak.

The ability to compete successfully seems to depend largely upon the extent to which the plants are massed in solid ranks; such a plant society is generally able to force out other plants from the territory available for occupation. The inherent vigor and hardiness of these plant societies due to their northern origin must also be reckoned in attempting to account for the success with which they compete with other forms.

V. CONCLUSIONS.

The work as presented in the foregoing pages is the result of an attempt to study the actual operations of known ecological factors and leave a record of existing conditions in the life history of a glacial lake and its flora. Little attempt has been made to discover new factors or to modify accepted ideas of ecological principles. Most of the statements made can be verified by actual observation; some must be inferred from present conditions. If carried farther, the work should consist in verifying certain statements either by subsequent observation or by laboratory experiment. The results of my study may be summed up as follows:

1. The comparative scarcity of terrestrial plants is a result of the former exclusively hydrophytic conditions which gave aquatic species an advantage which has since been maintained by all other hydrophil species.

2. There is a striking predominance of northern species, undoubtedly the result of the glacial invasion of recent geological times, and of conditions which tend to reproduce boreal environment.

3. The strength of the tension line between zones is increased by the soil-forming activities, because the soil which each zone produces makes the lake more unfit for it and fit for the succeeding zones.

4. An interaction of organic and inorganic agencies has caused and is now causing an unmistakable advance of plants into the lake, which is gradually being filled by the soil they produce. The more important among these agencies are soil, light, and morphological advantages.

5. The struggle for existence in each zone is less successful on the landward than on the lakeward side of that zone.

6. The plants engaged in this severe struggle show a marked tendency to mass themselves in solid ranks.

Botanical Laboratory,
University of Michigan.

BRIEFER ARTICLES.

THE TRICHOME STRUCTURES OF ERODIUM CICUTARIUM.

(WITH FOURTEEN FIGURES)

THE results of observations made by the present writer on the trichomes of Erodium are so different from those recently published in this journal[1] that it has seemed worth while to present them in some detail. About four more or less distinct forms of trichomes were found, some of these are glandular, others non-glandular.

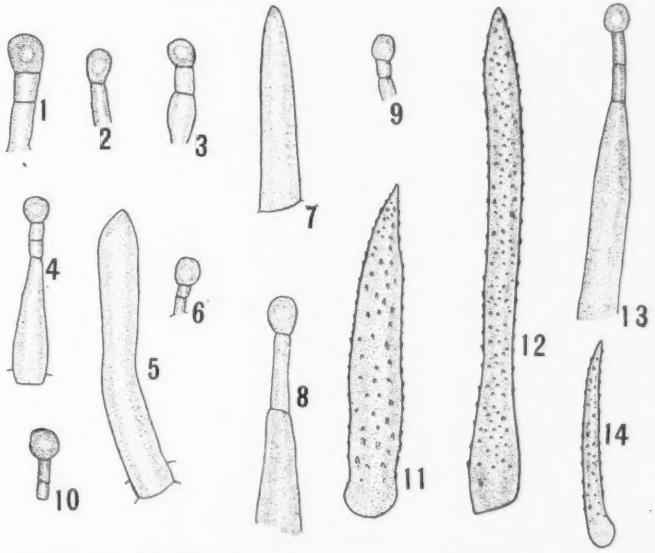
The trichomes of the hypocotyl are chiefly two to three-celled short filaments tipped with a bulbous glandular cell (*figs. 1, 2, 3*). Those of the cotyledon are various; thus the petiole bears some very short glandular hairs (*fig. 6*) smaller than those of the hypocotyl, also a kind with a long somewhat tapering basal cell (*fig. 4*). In addition to these glandular hairs there are some large unicellular hairs (*figs. 5, 7*) scattered here and there among the others. The blade of the cotyledon has in the basal sinus some of these same simple hairs. On other parts of the blade the hairs are glandular. Most of them are short (*fig. 9*), but there are also some longer ones (*fig. 8*) similar to some of those on the petiole (*fig. 4*).

The ordinary foliage leaves are somewhat different from the cotyledons in the trichomes they bear. The petioles have a great number of small glandular hairs (*fig. 10*), and in some specimens not a few longer hairs (*fig. 13*). Often these longer ones consist of five or six cells. In every case the proximal cell is far larger than the others. A thick-walled, rough tuberculate trichome (*fig. 11*) is also present. The leaves are pinnately divided and, as would be expected, the rachis has about the same trichome structures as the petiole. The long tuberculate form (*fig. 12*), however, is somewhat more common than the others, and is here longer than on the petiole. Sometimes these tuberculate structures are two-celled, but this is not a common occurrence. Scattered glandular hairs are also present like those seen on other parts (*figs. 8, 10*). The leaf blades bear many short tuberculate hairs. These are of different sizes. *Fig. 14* shows the most usual size and

[1] PRESTON, CARLETON E., Two instructive seedlings. BOT. GAZ. 33:150. 1902.

form, but some are like *figs. 11* and *12*. They are placed chiefly on the margin of the leaf blade and along the course of the vascular bundles. With them are many short, glandular hairs like those of the petiole (*fig. 10*).

It may be noted that Solereder[2] notes the presence of the glandular hairs which are here described and figured. He states that in Ero-



Trichomes of *Erodium cicutarium: 1, 2, 3*, from the hypocotyl; *4, 5, 6, 7*, from the stalk of the cotyledon; *8, 9*, from the blade of the cotyledon; *10, 11*, from the leaf petiole; *12*, from the rachis; *13*, from the leaf petiole; *14*, from the leaf blade; all × 170.

dium, Geranium, and Pelargonium the cells of the stalk may be all alike or the basal one may be swollen to form a pedestal-like structure (*cf. figs. 9* and *10* with *8* and *13*).

Careful search was made both on the early and later leaves for trichomes with the form of *figs. 4, 8*, and *13*, but with the basal cell thick-walled tuberculate. None were found on the material studied, although reported in the paper previously cited. Beside this difference in my own and Mr. Preston's results there are many others. He states

[2] SOLEREDER, Syst. Anat. d. Dicotyledonen. p. 193. 1899.

that the only modified epidermal structure of the cotyledon is the multicellular glandular hair (represented by my *fig. 8*), while I found all those shown in my *figs. 4–9*. He did not examine the hypocotyl.

By consideration of his results Mr. Preston builds up a theory of the phylogeny of these trichome structures which at once falls to the ground in view of the results reached by me. It seems scarcely worth while to propound theories of phylogeny based on a few observations on a single species. I think also that the theory of the above named writer to account for the lobing of the cotyledons is of no great value. He suggests that the lobing of the foliage leaf is "thrown back" upon the cotyledon. This assumes firstly that "throwing back" can actually occur, while as a matter of fact it yet remains to be proven; and secondly that the cotyledons are homologous with leaves, something which also remains unproven. The suggestion[3] concerning the morphology of the cotyledon made at the recent Chicago meeting of botanists of the central states seems more reasonable than the one which would consider the cotyledon as really a leaf.—FRANCIS RAMALEY, *University of Colorado.*

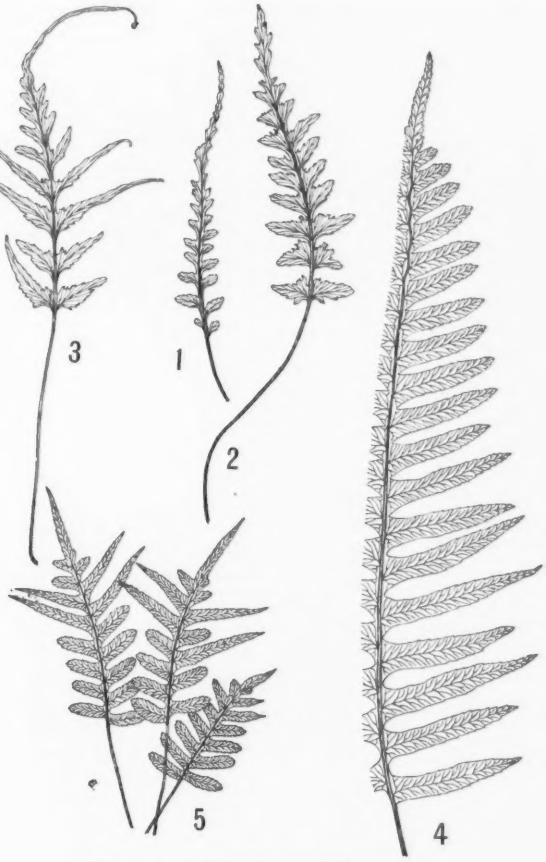
TWO FERN MONSTROSITIES.

(WITH FIVE FIGURES)

DURING the summer of 1900 two remarkable fern monstrosities were found on the Laurel ridge, in northern West Virginia. *Asplenium pinnatifidum* Nutt. was found on a spot on the north side of the rocky cañon of Decker's creek, at an altitude of about 1400 feet. There were not a dozen plants, all told, and none of them were quite normal. The species is abundant and typical four miles to the north, across the Cheat. The three accompanying figures illustrate the variability of the Decker's creek material, and will describe the fronds better than words can do. Individual fronds on most, but not on all, of the plants were typical, and insure the determination. Fruiting fronds had normal sori. There were no rooting tips. The region is rather rich in ferns, but I could not find Camptosorus in the immediate neighborhood. The "*Asplenium ebenoides*" described by C. E. Waters in *Fern Bulletin* of January 1902, with three different fronds on one plant, is remarkably like this monstrosity.

[3] LYON, HAROLD L., The phylogeny of the cotyledon. To be published in *Postelsia*, Annual of the Minnesota Seaside Station, season of 1891.

Polypodium vulgare L. was found in one of the formations known locally as "rock cities," flat hilltops of sandstone, broken so as to leave



FIGS. 1–3. Asplenium pinnatifidum.
FIGS. 4–5. Polypodium vulgare acuminatum.

parallel "streets" twenty or thirty feet deep and not so wide at an elevation of about 2000 feet. Typical plants were abundant. But in one small patch, hardly more than ten feet square and covering one free rock, there was a marked tendency toward pointed tips of the

frond segments. On young fronds especially the segments near the apex were often more than twice their normal length, and acuminate. On older fronds the modification was less excessive, and occurred as frequently on basal segments. This looks like as distinct a freak as var. *cristatum* or var. *cornutum*, or any of the monstrosities listed with names in Rabenhorst's *Kryptogamen-Flora*. If a name for it is worth while, it might be called monstr. *acuminatum*.

While they are not necessarily any support for De Vries' views on the origin of new plant forms, the value of such freaks as these in the study of the questions De Vries has brought prominently to the fore is self-assertive.— EDWIN BINGHAM COPELAND, *The University of Chicago*.

CURRENT LITERATURE.

BOOK REVIEWS.

Goebel's Organography.

THE FIRST PART of the second volume of this great work on the organography of plants has already been reviewed in this journal.[1] The second and concluding part,[2] now before us, deals almost exclusively with reproduction in pteridophytes and seed plants. The principal subjects are (1) the function of the shoot in reproduction, under which are included the flowers and sporophylls of pteridophytes, gymnosperms, and angiosperms; and (2) the reproductive organs, the principal headings being the mature sporangia of pteridophytes, development of sporangia, hypothetical phylogeny of the formation of sporangia, apospory, microsporangia of seed plants, megasporangia of seed plants.

The work, in large part, is based upon the author's own observations, and many facts in the development of pteridophytes and spermatophytes, as well as the theories drawn from them, are published here for the first time. As might be anticipated from the writer's previous work, the biological side of the subject is strongly emphasized. It is interesting to note that the term "flower," while not made sufficiently elastic to include the sporangial region of Onoclea, is nevertheless extended beyond the spermatophytes and applied to the strobili of Equisetum, Selaginella, etc. According to the author, a flower is "a shoot beset with sporophylls," but how far the boundary is to be pushed is a subjective matter. Bisporangiate flowers are regarded as primitive, most monosporangiate flowers being due to suppression. Bower's classification of the ferns into Simplices, Gradatae, and Mixtae is regarded as useful.

It is very unfortunate that the book contains no index. The table of contents is rather full, but cannot supply the place of an index when one wishes to find some particular thing without a provoking delay. The references to literature are meager and indefinite, and are to be found only as footnotes. The book is essential to the morphologist and ecologist, and it is to be hoped that the English translation will not be long delayed.—CHARLES J. CHAMBERLAIN.

[1] BOTANICAL GAZETTE 31: 204. 1901.

[2] GOEBEL, K., Organographie der Pflanzen insbesondere der Archegoniaten und Samenpflanzen. Zweiter Teil. Specielle Organographie. 2 Heft: Pteridophyten und Samenpflanzen. Zweiter Teil. 8vo. pp. 649–828. 107 illustrations. Jena: Gustav Fischer, 1901. *M* 5.

MINOR NOTICES.

DR. ROLAND THAXTER,[3] in continuing his studies of Laboulbeniaceae, has described numerous new species, adding no fewer than forty to the genus *Laboulbenia*, and describing as new genera *Herpomyces* (9 spp.), *Acallomyces*, *Ecteinomyces*, and *Coreomyces* — J. M. C.

THE NINTH PART of Wiesner's *Die Rohstoffe des Pflanzenreiches*[4] concludes the nineteenth section on *Unterirdische Pflanzentheile* (to p. 571), contains the twentieth part on *Blätter und Kräuter* (pp. 572–625), and begins the twenty-first part on *Blüthen und Blüthentheile*.— J. M. C.

MISS ALICE EASTWOOD has published a *Flora of the South fork of King's river*, being no. 27 of the publications of the Sierra club. This is the first attempt to prepare a manual of the flora of the southern Sierra Nevada; and the purpose of this preliminary publication is both to record the plants of an interesting region and to provide a simple guide for those not specially trained.— J. M. C.

PARTS 213 and 214 of Engler and Prantl's *Natürlichen Pflanzenfamilien* have appeared.[5] The former contains the conclusion of the Isoetaceae by R. Sadebeck, and Cycadofilices, Cladoxyleae, Lyginopterideae, Medulloseae, Cycadoxyleae, Protopityeae, and Araucarioxyla by H. Potonié; also a supplement on Marattiaceae and Ophioglossaceae by von Bitter. The latter part contains a continuation of the Pottiaceae by V. F. Brotherus.— J. M. C.

Y. YABE[6] has published a revision of the Umbelliferae of Japan, the prefatory notes being in English, and the body of the paper in Japanese. The revision includes 40 genera and 95 species, 28 being endemic, and 12 introduced. The largest genus is Angelica, in which several new species are described. The author appears not to have had access to the recent *Monograph* by Coulter and Rose, all reference to their work being in connection with the much earlier *Revision*.— J. M. C.

PERCY LEROY RICKER has published "A preliminary list of Maine fungi," being no. 3 of *The University of Maine Studies*. A "historical sketch of the study of the Maine flora" is given, followed by a "list of works and papers treating of Maine fungi." So far as possible, the collection containing the specimen cited is named, so that the right of any species to be

[3] Preliminary diagnosis of new species of Laboulbeniaceae. V. Proc. Amer. Acad. **38**: 9–57. 1902.

[4] WIESNER, JULIUS, Die Rohstoffe des Pflanzenreiches, etc. Volume II, pp. 481–640. *figs. 156–199*. Leipzig: Wilhelm Engelmann, 1902. *M* 5.

[5] Press of Wilhelm Engelmann, Leipzig.

[6] Revisio Umbelliferarum Japonicarum. Reprint from Jour. Coll. Sci. Imp. Univ. Tokyo. **16**^{2}: [repaged] 1902.

regarded as a member of the flora can be tested. The classification is that of Saccardo's *Sylloge Fungorum*. The list includes 370 genera and 1136 species.— J. M. C.

PROFESSOR AVEN NELSON[7] has prepared a *Key* to the common flowering plants of the Rocky mountain region, to be used by elementary classes of secondary schools in their first contact with the local flora. Such keys are insisted upon by publishers, much to the discomfort of botanists. But if they are to be published at all, they should be prepared by some one familiar with the flora. For the region presented in the *Key* before us no better selection could have been made than Professor Nelson, and every page shows familiar field contact. A few hundred plants of the spring and early summer are selected from the thousands belonging to the flora, and their descriptions and the keys are admirably simple and direct. Of course the author hopes that the little book will serve in inducing the proper study of the flora through the regular manuals.— J. M. C.

C. H. OSTENFELD,[8] Inspector of the Botanical Museum of the University of Copenhagen, has undertaken to edit an illustrated arctic flora, published in English, the first part of which has just appeared. At the suggestion of Professor Warming, it was begun by the late Mr. O. Gelert, who had associated Mr. C. H. Ostenfeld with him. In March 1899, Mr. Gelert died, but about half of Part I may be credited to him. The ferns and seed plants of the arctic regions are recorded in many scattered lists, each author using his own nomenclature, so that their study is quite troublesome, This *Flora Arctica* includes all regions north of the limit of trees. A prefatory bibliography cites about 95 titles. The pteridophytes are represented by 30 species; the gymnosperms by 3; and the monocotyledons by 179, 54 of them being species of Carex. The printing and figures are excellent, the descriptions clear and sufficiently full, and the keys very simple.— J. M. C.

HEALD'S *Elementary Biology*[9] is a laboratory guide covering a year's work for college students. It is unique in that there is as much space devoted to plants as to animals. Directions for working out a specimen of each of the great plant groups, including Schizophytes, Fungi, and Lichens,

[7] An analytical key to some of the common flowering plants of the Rocky mountain region. pp. vii + 94. New York: D. Appleton & Co. 1902.

[8] Flora Arctica, containing descriptions of the flowering plants and ferns found in the arctic regions, with their distribution in these countries. Part I. Pteridophyta. Gymnospermae, and Monocotyledones, by O. GELERT and C. H. OSTENFELD. Published by the Carlsberg fund: Copenhagen. 1902.

[9] HEALD, F. D., Laboratory manual of elementary biology. 8mo. pp. viii + 287. Binghamton (N. Y.): Willard N. Clute & Co. 1902.

are given in minute detail. The forms described were chosen evidently upon the basis of their widespread distribution, rather than because they are typical of the groups they illustrate, or are important from the standpoint of evolution. Spirogyra, Vaucheria, and Chara are the filamentous forms selected to give the student an impression of the green algae, and Marchantia is the only liverwort. It is an open question whether the day for laboratory guides has not passed. The well-trained teacher does not need one—finds it a hindrance in maintaining the plasticity of laboratory work, which should change year after year with the availability of desirable material and the personnel of the class.—F. M. LYON.

A NEW LABORATORY MANUAL of botany has been provided by Dr. Otis W. Caldwell.[10] The book is the result of direct and personal contact with the needs and possibilities of botanical instruction in secondary schools of the middle West. It has avoided the too detailed and technical directions of manuals better adapted to colleges than secondary schools; and at the same time selects the essential features of the subject as now presented in the best schools. It does not seek to eliminate the teacher or the good reference book, but depends upon both to fill out and coordinate. It well meets the demands of schools where time and facilities and the age of pupils forbid the demands often made by zealous but inexperienced university instructors. A good selection of material is presented, so that there may be no difficulty in securing something illustrative. Of course, the wooden teacher will think that everything mentioned is to be used, but for such no suitable book can be written. The first part of the manual suggests ecological and physiological studies; the second part deals with the essentials of morphology.—J. M. C.

THE NINTH PART[11] of Engler's *Pflanzenreich* is a book of 437 pages, containing the Myrsinaceae by Carl Mez. After the usual introductory discussion, the 32 genera of this great tropical family are presented. The seven new genera are *Conandrium*, *Sadiria*, *Afrardisia*, *Tetrardisia*, *Amblyanthopsis*, *Discocalyx*, and *Grenacheria*. The total number of species described is 933, of which 348 are new. The large genera are Ardisia (235 spp.), Rapanea (136 spp.), Maesa (102 spp.), and Embelia (92 spp.). The fossil forms of nine genera are also described. The vast amount of material to be investigated in a single family like this is an impressive illustration of the magnitude of the work undertaken by Professor Engler and his associates.

[10] A laboratory manual of botany. pp. x + 107. New York: D. Appleton & Co. 1902.

[11] ENGLER, A., Das Pflanzenreich. Regni vegetabilis conspectus. Heft 9. Myrsinaceae von Carl Mez, pp. 437. Leipzig: Wilhelm Engelmann, 1902. *M* 23.

The tenth part[12] contains the Tropaeolaceae by Fr. Buchenau, who recognizes 50 species, but describes no new ones. The eleventh part[13] contains the Marantaceae by K. Schumann, who after a somewhat detailed preliminary discussion presents the 26 genera, 11 of which (*Actoplanes*, *Sarcophrynium*, *Stachyphrynium*, *Halopegia*, *Afrocalathea*, *Monophrynium*, *Ctenophrynium*, *Phacelophrynium*, *Pleiostachya*, *Monophyllanthe*, and *Monotagma*) are described as new. The species number 277, the large genus being Calathea with 103 species, and 42 new species are described.— J. M. C.

IN A PAPER on plant distribution Bruncken[14] has contributed some valuable ecological data. The first topic is the succession of forest types in the vicinity of Milwaukee. Three mesophytic associations are discussed; viz., oak, basswood-maple, and elm-ash. The oak is the most prevalent, though evidence is not lacking that it would become replaced by the basswood-maple association if not interfered with by man. Mixed with the basswood and maples near Lake Michigan the beech is found. This, the author states, is probably due to lake climate. There is evidence that a more xerophytic forest of white pine and white birch once prevailed along the lake shore. The second topic is the distribution of the genus Viola. After a careful study of the distribution of the various species, the author concludes that the occurrence of the more or less xerophytic species depends on the amount and quality of the humus. The third topic is the upland brushwoods of the Milwaukee region, their typical development being treated in detail. The fourth section is a list of plants collected on the Door co. peninsula, Wisconsin; the fifth discusses the forests and brush lands of northern Waukesha co., Wisconsin; the sixth presents lists of eastern Wisconsin plants from the herbarium of the Milwaukee Public Museum; the seventh is entitled "A tamarack swamp in Waukesha co.;" and the eighth is a list of plants from Sheboygan.— H. N. WHITFORD.

A HANDBOOK of New England trees by Dame and Brooks[15] has been added to the list of popular works in botany. Each tree is discussed under several topics, as the habitat and range, habit, bark, winter buds and leaves, fruiting characters, and the horticultural value. The description of the bark and of the winter buds will facilitate the identification of trees in their winter condition. The distribution of the trees in the different New England

[12] *Ibid.* Tropaeolaceae von Fr. Buchenau, pp. 36. *M* 1.80.

[13] *Ibid.* Marantaceae von K. Schumann, pp. 184. *M* 9.20.

[14] BRUNCKEN, ERNEST, Studies in plant distribution. Bull. Wisconsin Nat. Hist. Surv. **2**: 17–28, 137–169. 1902.

[15] DAME, LORIN L., and BROOKS, HENRY, Handbook of New England trees, with ranges throughout the United States and Canada. Boston: Ginn & Company, 1902. $1.35.

states is given with great care and thoroughness. In the case of trees of infrequent or rare occurrence the authority for each station is given. The accuracy of these citations is made still more prominent by a list of authorites cited and of the trees with reference to which each is quoted. The discussions of the habit of trees also show clearly the result of accurate and painstaking field observations. The book is illustrated from excellent drawings by Mrs. Elizabeth Gleason Bigelow. If this volume is to help the student in the field, as the authors purpose, one would wish that the distinguishing characters of the trees were more fully emphasized. The fact that the New England pines, for example, with one exception, may be readily distinguished by the number of leaves in a sheath is not made prominent. A beginner might read several pages before knowing this simple guide to the pines. A combination of the fruit and leaf characters of the elms, birches, maples, and poplars often furnishes a ready test for the determination of the species. That such facts are emphasized, perhaps with one exception, neither by keys nor by typographic arrangement, will detract from the serviceableness of this pocket-sized volume in actual field work. Throughout the volume the authors use the terms fertile and sterile in referring to staminate and pistillåte flowers. Such terms perpetuate a mistaken conception, and they are too antiquated for the present knowledge of plant reproduction. With these two exceptions this volume has a stamp of thoroughness and accuracy not often found in botanical handbooks designed for popular use.—C. D. HOWE.

A FLAX DISEASE of wide distribution and much economic importance has been diagnosed, studied, and traced to its cause by Professor Henry L. Bolley,[16] of the North Dakota Agricultural College; and what is of practical moment an efficient method has been found to check or possibly wholly prevent the disease. Every cultivatór knows that only a few successive crops of flax can be grown on a given piece of land with profit. The yield constantly decreases, and no system of manuring or cultivation has been found to overcome the difficulty. An interval of seven to eleven years is required before flax can be grown again with profit upon such a field. The trouble appears to exist alike throughout Europe and America. It is now ascertained to be due to a fungus, introduced chiefly with the seed, which is described as a new species of Fusarium, as follows:

FUSARIUM LINI Bolley in Bull. N. D. Agric. Station no. 50. p. 37. Vegetative hyphæ light colored, 0.7–3 μ in diameter, septate, branching irregularly, ramifying the tissue of the stem and roots of the host. Spore beds (sporodochia) erumpent, compact, slightly raised, distinct but closely grouped upon the stems, pale cream to flesh-colored. Sporophores rather short and closely branched, or conidia sometimes arising from wart-like or nearly sessile prominences upon a compact stromatic base.

[16] BOLLEY, H. L., Flax wilt and flax-sick soil. Bull. N. D. Exper. Station, no. 50; pp. 27–57. 1901.

Conidia normally four-celled, fusiform, slightly curved or falcate, copiously produced in a bud-like manner from the stroma and from short branches of the sporophores, $27 \times 3\,\mu$ to $38 \times 3.5\,\mu$. Living in the humus of the soil, able to attack the flax plant, producing the disease known as "flax wilt," and causing the soil condition described as "flax-sick soil."

This fungus attacks the young plants of flax and spreads somewhat slowly to older plants, and has the power to maintain itself for sometime saprophytically. The preventive is to moisten the seed before sowing with a solution of formaldehyde, care being taken to have the seed well cleaned, as no means have been found to disinfect bits of straw and imperfect seed mixed with good seed.

The bulletin is a fine example of deductive and experimental research.—J. C. ARTHUR.

THE BOTANICAL INSTITUTE of the University of Brussels has begun to publish a collection of its work, of which Vol. V, with papers dated 1900 to 1901, is first to appear.[17] Vols I–IV, containing papers from 1882 to 1900, are in preparation. The volume at hand has the following attractive contents: G. CLAUTRIAU, Nature et signification des alcaloïdes végétaux, and La digestion dans les urnes de Nepenthes; E. VANDERLINDEN, Recherches microchimiques sur la présence des alcaloïdes et des glycosides dans la famille des Renonculacées, with 2 colored plates; J. MASSART, Le lancement des trichocystes chez *Paramoecium Aurelia*, Sur le protoplasme des Schizophytes with 6 colored plates, and Essai de classification des réflexes non nerveux; L. ERRERA, Sur la myriotonie comme unité dans les mesures osmotiques, and Sur une Bactérie de grandes dimensions: *Spirillum Colossus;* FR. VAN RYSSELBERGHE, Influence de la température sur la perméabilité du protoplasme vivant pour l'eau et les substances dissoutes; J. STARKE, De la prétendue existence de solanine dans les graines de Tabac.

In the system proposed by Errera for the measurement of osmotic and gas pressures, the "tonie" is the pressure of 1 dyne on 1 $^{sq.cm}$ of surface; 10000 of these make the myriotone, which is approximately $\frac{1}{100}$ of an atmost phere. In the equation $pv = RT$, if p is expressed in myriotones, R equals 8.32. The osmotic pressure of 0.1 mol. KNO_3 is computed as *ca.* 443 myriotones, considerably higher than the commonly accepted figure. Van Ryssel-berghe finds that while the temperature has great influence on the rapidity of the movement, water and various other substances (glycerine, urea, cafeine, methylene blue, and ammonium carbonate) can pass slowly through the protoplasm at zero. He holds that the slightest pressure is adequate, if given time, to force water through protoplasm or any other permeable mem-

[17] Recueil de l'Institut Botanique (Université de Bruxelles) publié par L. Errera. Tome V. Bruxelles. 1902.

brane. Massart, on the protoplasm of the Schizophytes, concludes that the central body, even when it occurs, is not the homologue of a nucleus; nor is the "couche corticale" the homologue of a plastid. He regards the Schizophyceae as derived from the bacteria, but the group as a whole as nowise related to any other organisms. In his last paper, Massart introduces a deluge of new terms sufficient alone to form a supplement to any up-to-date dictionary. The analysis of the subject is clear, and in large part logically carried through; and a clean-cut vocabulary is prerequisite to clean-cut thinking, still more to lucid expression. Codifying such a terminology is an unqualified service to those who use it, as Czapek's forerunner has well proven, but every uninitiate will want to go armed with a "Nomenclator Massartianus" before "geanisopachynosis," "tonesagogic," "cathaptotropic," and the scores more like them become familiar terms.— E. B. COPELAND.

NOTES FOR STUDENTS.

NINE SPECIES of the Corallinae (verae) from Port Renfrew are described and figured by K. Yendo.[18] Three of these are new species, viz., *Cheilosporum MacMillani*, *Corallina vancouveriensis*, and *Corallina aculeata*.— B. M. DAVIS.

THE NEW *Oscillatoria beggiatoides* is a colorless sulphur-bearing organism described by Arzichowsky,[19] and considered by him as a transition between Oscillatoria and Beggiatoa. The sulphur grains are very small and lie close to the cell wall. The account of this interesting form is to be found among the descriptions of several species of Beggiatoa. It deserves better treatment in a language and a journal that will reach more botanists. The paper is written in Russian, with a very short and unsatisfactory résumé in German.— B. M. DAVIS.

PTERYGOPHORA CALIFORNICA is described and figured by MacMillan,[20] who presents some interesting observations on its anatomy and development. Pterygophora is a surge plant growing below the zone of Lessonia and above that of Nereocystis. The general morphology is closest to Alaria, but the distribution of the sori found in the lateral pinnae, together with the "disposition of cuticular caps in the paraphyses," suggest Lessonia. Some of the plants are very large, being ten feet long with stalks three inches in diameter.

[18] YENDO, K., Corallinae verae of Port Renfrew. Minn. Bot. Studies II. **6**:711–722. *pls. 51–56*. 1902.

[19] ARZICHOWSKY, W., Zur morphologie und systematik der Beggiatoa Trev. Bull. Jard. Imp. Bot. **2**:45–46. *pl. 1*. 1902.

[20] MACMILLAN, CONWAY, Observations on Pterygophora. Minn. Bot. Studies II. **6**:723–741. *pls. 57–62*. 1902.

The latter show rings of growth. The young plants have a single blade, as is true of all kelps, the lateral pinnae developing as outgrowths from the stipe below the blade in a manner similar to Alaria.— B. M. DAVIS.

HABITUAL POLYEMBRYONY has been observed by Hegelmaier[21] in *Euphorbia dulcis* Jacq. In about two-thirds of the half ripe seeds there is more than one embryo, the number ranging from two to nine. In the ripe seed the number is smaller, usually two or three, and one of these considerably larger than the others. The embryo which develops from the egg is the only one which has a suspensor, and is also the one which becomes the largest embryo in the ripe seed. Of the other embryos, some come from synergids and some from cells of the nucellus. A large per cent. of the polyembryonic seeds are not capable of germinating on account of the disorganization of the embryo.— CHARLES J. CHAMBERLAIN.

THE TIMOTHY RUST, which has generally been referred to *Puccinia graminis* Pers., was set apart by Eriksson as the result of cultures in 1891–93, under the name *Puccinia Phlei-pratensis* E. & H. In a recent article[22] the work of this period is critically examined, and many additional cultures, made during 1894–1900, are reported. The conclusion is reached that the species is autonomous, that it occurs on *Phleum pratense* and *Festuca elatior*, and that it may be transferred sparingly by cultures to *Phleum Michelii*, *Avena sativa*, and *Secale cereale*, but not to *Phleum asperum*, and other grasses. Neither will it infect the barberry, and it appears to have lost the power to form aecidia. It is doubtful if this species occurs in America. It has been reported under the name *P. graminis* once upon *Festuca elatior* (Vermont, 1898), but examination of the original material reveals an error; and once upon *Phleum pratense* (Wisconsin, 1884), which has not been re-examined. —J. C. ARTHUR.

HASSENKAMP[23] describes the development of the cystocarp in two red algae, *Thuretella Shousboei* and *Chylocladia kaliformis*, and his results support Oltmanns' theory of the relation which the auxiliary cells bear to the fertilized carpogonium. He finds that when the carpogonium fuses with an auxiliary cell, the respective nuclei remain quite apart, so that the union concerns the cytoplasm alone. The sporogenous nuclei (sporophytic) are then active in developing the fertile portions of the cystocarp with the spores.

[21] HEGELMAIER, F., Ueber einen neuen Fall von habitueller Polyembryonie. Ber. Deutsch. Bot. Gesells. **19**: 488–499. 1901.

[22] ERIKSSON, JAKOB, Ist der Timotheengrasrost eine selbständige Rostart oder nicht? Öfv. K. Vet.-Akad. Förh. 1902: 189–198.

[23] HASSENKAMP, A., Ueber die Entwickelung der Cystocarpien bei einigen Florideen. Bot. Zeit. **60**: 65–86. *pl. 2. figs. 12.* 1902.

The results for Chylocladia are especially interesting, since they flatly contradict the conclusions of Hauptfleisch (Flora **75**: 306. 1892). The latter described a number of secondary cell and nuclear unions following the sexual act and resulting in a large fusion cell. Hassenkamp seems to have overlooked a paper of mine (BOT. GAZ. **21**: 109. 1896) which showed that Hauptfleisch's results for Champia, a genus closely related to Chylocladia, were incorrect. This omission is the more conspicuous since Oltmanns (Bot. Zeit. **56**: 128. 1898) tried to smooth over the grave errors of Hauptfleisch by assuming that we were not dealing with the same form. Champia probably presents the same conditions as Chylocladia, as may be judged by comparing my figures with Hassenkamp's.— B. M. DAVIS.

KOHL[24] describes an accurate method of measuring the expansion and contraction of pith cylinders, etc., when placed in solutions of different concentrations. The object to be studied is fastened upright by its base in a suitable chamber provided with entrance and exit tubes for the application and changing of plasmolyzing solutions. To the upper end of the object is attached a thread which travels over two small pulleys at the same height and some distance apart. It is sufficiently weighted at its other end to remain taut, and bears a pointer between the pulleys. This pointer traverses a fixed horizontal scale which furnishes a means of measurement.

In the same paper is described a new form of self-registering auxanometer which the author designates as *photographic*. A revolving cylinder, covered with a sensitized collodion film, is enclosed in a dark box, in one of whose sides is a vertical strip of metal provided with an opening of 1^{mm} diameter. This strip is long enough to allow vertical movement without admitting light excepting through the opening. A minute incandescent lamp is fixed to the strip in such a manner that the rays from the lamp traverse the opening at right angles to the strip, and impinge upon the revolving film within the box. By means of a filament passing over a wheel the sliding strip may be fixed to any object whose upward movement is to be studied. As this rises the beam of light moves downward over the film, which, of course, will need to be developed in the usual way to bring out the record.— B. E. LIVINGSTON.

EDWARD C. JEFFREY[25] has published a paper entitled "The structure and development of the stem in the Pteriodophyta and Gymnosperms." The author reaches the following morphological conclusions: There are two types of cauline central cylinder, protostelic and siphonostelic; the protostelic central cylinder is more primitive, and in its single concentric vascular strand no medulla is present; the siphonostelic central cylinder is tubular,

[24] KOHL, F. G., Ein neuer Apparat zur Demonstration von Wachstums und Plasmolyse-Erscheinungen. Ein photographisches Auxanometer. Ber. Deut. Bot. Gesells. **20**: 208–212. 1902.

[25] Phil. Trans. Roy. Soc. London B. **195**: 119–146. *pls. 1–6*. 1892.

has a medulla derived from the fundamental tissue, and is characterized by the presence of foliar and ramular lacunae, or by ramular lacunae only; the siphonostelic central cylinder sometimes ceases to be obviously tubular in the adult, and in such cases may be termed adelosiphonic; the siphonostelic central cylinder is primitively concentric, but in the Angiosperms, Gymnosperms, Osmundaceae, etc., has become collateral by reduction; the pith is to be regarded as an inclosed portion of the fundamental tissue. The phylogenetic features of the results are as follows: There are two phylogenetic types of tubular central cylinder, viz., that in which only ramular gaps are present, and that in which both ramular and foliar gaps occur, the former termed cladosiphonic, and the latter phyllosiphonic; the use of these constant and characteristic anatomical features results in the division of the Vaşculares into two great primitive stocks—the Lycopsida, which are cladosiphonic and palingenetically microphyllous, and the Pteropsida, which are phyllosiphonic and palingenetically megaphyllous; the former including the Lycopodiales and the Equisetales, the latter the Filicales, Gymnosperms, and Angiosperms.—J. M. C.

ITEMS OF TAXONOMIC INTEREST are as follows: ALICE EASTWOOD (Proc. Calif. Acad. Sci. III. Bot. **2**: 285–293. 1902) has described new species of Streptanthus, Polygonum, Eriogonum, Garrya, Convolvulus, Castilleia (3), Mimulus, Phacelia, Gilia, Cryptanthe, Aster, and Madia, all from the Sierra Nevada mountains of California.—W. A. KELLERMAN (Jour. Mycol. **8**: 50–51. *pl. 1.* 1902) has published a new species of Rhytisma on Ilex.—J. C. ARTHUR (*idem* 51–56) has published 3 new species of Puccinia.—ELLIS and EVERHART (*idem* 62–73) have published 59 new species of fungi from the vicinity of Tuskegee, Alabama.—P. HENNINGS (Hedwigia **41**: 104–118. 1902), in his first paper on Putteman's collection of fungi from São Paulo, has described as new genera *Puttemansia* (Pezizaceae), *Pseudomelasmia* (Leptostromataceae), and *Tetracrium* (Mucedinaceae); and from the Javanese collection of Zimmermann the same author (*idem* 142) has described a new genus (*Zimmermanniella*) of Dothideaceae.—J. B. S. NORTON (Trans. Acad. Sci. St. Louis **12**: 35–41. *pls. 5–8.* 1902) has published new species of Cyperus, Argemone, and Brauneria from the southwestern U. S.—T. MAKINO (Bot. Mag. Tokyo **16**: 119. 1902) has published a new genus (*Semiaquilegia*) of Ranunculaceae from Japan, said to be intermediate between Aquilegia and Isopyrum, and founded on *Isopyrum adoxoides.*—J. MATSUMURA (Jour. Coll. Sci. Tokyo **16**: pt. 2. *pls. 4.* 1902), in his revision of the Japanese species of Alnus, has described 3 new species.—K. YENDO (*idem pls. 7*), in a revision of the "Corallinae verae" of Japan, has described 20 new species.—ELMER D. MERRILL (Rhodora **4**: 142–147. 1902), in "Notes on N. Am. grasses," has described new species of Panicularia, Poa, Bromus, and Elymus.—J. M. C.

INTERCELLULAR KARYOGAMY is the term applied to that condition in the basidiomycetes by which the nuclei are associated in pairs throughout long periods of vegetative activity, but finally fuse in the basidium or teleutospore at the end of the vegetative phase in the life history. The fusion is believed by a number of investigators to be a sexual act, and the association of the nuclei in pairs for so long a time is considered an extension of the period when the gamete nuclei were really differentiated. There are several accounts of the fusion of nuclei in the basidium, several botanists claiming that only two nuclei enter this structure and fuse, while others (Wager and Rosen) have reported as many as three, four, six, and eight concerned with this phenomenon. Ruhland[26] in a recent paper throws the weight of his studies upon several of the hymenomycetes in favor of the predominance and possible universality of two primary nuclei entering the basidium and there uniting to form the secondary basidium nucleus, which later divides just previous to spore formation. His conclusions thus accord with the recent paper of Harper (BOT. GAZ. **33**: 1. 1902). We do not yet know when the paired condition of the nuclei arises in the life history of any basidiomycete, and this is a very important period, for events may occur at that time which make these nuclei physiologically gametes. However, it is much to know that these pairs of nuclei lie in a definite path of development which ends with their final fusion in the teleutospore and basidium. The more thoroughly we understand these processes in the basidiomycetes the sharper appears the distinction between them and nuclear fusions in the ascus. The two events have no morphological relation to one another. That in the ascus is certainly not concerned with gamete nuclei, whatever may be its physiological significance.— B. M. DAVIS.

[26] RUHLAND, W., Zur Kenntniss der intracellularen Karyogamie bei den Basidiomyceten. Bot. Zeit. **59**: 487–206. *pl.* 7. 1901.

NEWS.

THE UNIVERSITY OF VERMONT has received from Dr. W. Seward Webb, one of its trustees, the sum of $6000 for the purchase of the herbarium of C. G. Pringle.

IN CONNECTION with the Royal Botanical Gardens at Peradeniya an experiment station has recently been established for trying on a large scale new products not yet staples. The purchased estate contains 550 acres.

AT A RECENT MEETING of Congress the serial publication known as "Contributions to the U. S. National Herbarium" was transferred from the Department of Agriculture to the National Museum, with a special appropriation of $7000. This provides for an editorial assistant and an artist, and will enable the Museum to republish certain numbers which are out of print and in demand.

AT THE PITTSBURG meeting of the Botanical Club of the A. A. A. S., the Committee on Nomenclature made the following report through its chairman, Dr. N. L. Britton: "The committee reports that it has held meetings December 29, 1900, and June 30, 1902, and that through a sub-committee has drawn up the basis for a codification of the rules of nomenclature, including the determination of generic types, as previously authorized. The committee recommends that it be given authority to ask the cooperation of other botanists and zoologists in the further consideration of the subjects referred to it, and through their aid to prepare a list of as many types of North American genera as may be possible for presentation, with its report, at a future meeting."

AT THE PITTSBURG meeting of the Botanical Club of the A. A. A. S., C. L. Shear presided, and F. L. Stevens was appointed secretary-treasurer: The following program was presented: H. L. BOLLEY, An anthracnose of flax attacking the embryo within the seed coats; N. L. BRITTON, Carpellary structure of *Sedum pulchellum*, An undescribed species of Hydrophyllum; MEL. T. COOK, Notes on material for class demonstration; O. F. COOK, The sterility of coffee varieties, Facts from the history of the cocoa-palm; ARTHUR HOLLICK, A bud from a buried cypress swamp; A. D. HOPKINS, A blank for phenological notes; F. E. LLOYD, Mutual variation in opposite leaves, Vivipary in Podocarpus, A cheap and convenient laboratory aquarium, Museum methods: demonstration of life histories; C. L. POLLARD, The Gray polypod in Washington, D. C.; H. VON SCHRENCK, On the germination

of *Arceuthobium pusillum;* A. D. SELBY, A destructive disease of ginseng under cultivation caused by Alternaria sp., A disease of forced cucumbers apparently allied to the mosaic disease of tobacco, tomato, etc.; J. A. SHAFER, *Marshallia trinervata* (Walt) Porter in Pennsylvania, An interesting Heuchera; C. L. SHEAR, Notes on *Sclerodema pteridis*, n. sp.; F. L. STEVENS, Notes on Scelerospora, Notes on Symplocos and Salvia, A new character in Hexastylis; C. F. STEWART and H. J. EUSTACE, Frost blister of apple and quince leaves. The following officers were elected for the ensuing year: F. E. LLOYD, *president;* A. F. WOODS, *vice-president;* W. R. MAXON, *secretary-treasurer.*

THE RECENT SESSIONS of the Botanical Society of America in Pittsburg marked an important epoch in the history of that organization, and may be taken to be of great importance to the botanical interests of the entire country. Although in existence but eight years as an organization, the funds in the hands of the treasurer now amount to over $2,700. By the adoption of a resolution at the Denver meeting in 1901 the society committed itself to the policy of expending $500 per year in grants in aid of investigations as soon as the state of its finances would permit. The income and funds of the society have shown a gratifying and unexpected increase, and this feature of the policy of the society is to be put in force at once, as indicated by the resolutions given below. It is notable that the grants to be made by the society form an example of perhaps the only series of scientific grants ever offered in America by means of funds contributed by actual workers in the branch of science benefited. The first grants may be made at the coming meeting in Washington, as indicated by the resolutions:

Resolved, That applications in aid of investigations may be made at any time by members or associates in good standing. Such applications should be made to the secretary, accompanied by a detailed statement in regard to the work for which the grant is requested, and shall be referred by the secretary to the council. The council shall report upon all applications at the next meeting subsequent to the date at which they are received. The amount of any grant confirmed by the society may be drawn by the applicant from the treasurer within six months after the meeting at which the grant was made, after a proper receipt has been made therefor.

The recipient of a grant must make a report of the progress or of the completed results of the investigations for which the grant was given at the next annual meeting, and at every succeeding meeting until the work in question is finished. Such report must be made in writing to the council, and may or may not be referred to the society. Any and every paper dealing with the results of investigations carried out by the aid of grants as above shall bear the imprint, "Investigations prosecuted with the aid of a grant from the Botanical Society of America."

Resolved, That at the next meeting of the society a grant or grants in aid of investigation may be made in any amount not to exceed the total sum of five hundred dollars ($500.00) to members and associates of the society.—D. T. MACDOUGAL, *Secretary of Botanical Society of America.*

THE FOLLOWING PAPERS were read before section G of the A. A. A. S. at the recent Pittsburg meeting: JOHN M. BATES, The finding of *Puccinia phragmitis* (Schum.) Korn. in Nebraska; CHARLES E. BESSEY, An instance of a change in the native flora, Note on the fuel value of cottonwood; CHARLES J. CHAMBERLAIN, The origin of the achromatic figure in Pellia; MEL T. COOK, Comparison of the development of the embryo sac and embryo of *Claytonia Virginica* and *Agrostemma Githago;* JOHN M. COULTER, Special haustorial apparatus in connection with the embryo sac of angiosperms; EDWIN B. COPELAND, The ascent of the transpiration stream, Chemical stimulation and the evolution of carbon dioxid; J. W. T. DUVEL, Conditions influencing the vitality and germination of seeds; H. A. HARDING and F. C. STEWART, A bacterial soft rot of certain cruciferous plants and *Amorphophallus simense*, a preliminary report; GEORGE G. HEDGCOCK, The prevalence of Alternaria in Nebraska and Colorado during the drought of 1901; A. S. HITCHCOCK, Notes on Agrostis; MARSHALL A. HOWE, A note on the vitality of the spores of Marsilea; HENRY KRAEMER, The pith cells of *Phytolacca decandra;* D. T. MACDOUGAL, Soil temperatures and vegetation; J. B. S. NORTON, *Sclerotinia fructigena;* GEORGE J. PEIRCE, Some neglected factors in discussions of heredity; CHARLES L. POLLARD, Features of the flora of Cuba; FRANK W. RANE, Effect of acetylene gas-light on plant growth, plant environment, and plant diseases; HERMANN VON SCHRENK, Notes on diseases of western Coniferae; AUGUST D. SELBY, A disease of potato stems in Ohio due to Rhizoctonia; C. L. SHEAR, *Arachniotus trachyspermus*, a new species of the Gymnoascaceae; F. L. STEVENS, Studies in Phycomycete fertilization, *Sclerospora gramnicola* (Sacc.); F. L. STEWART, The absorption of water; a function of the ligule and stipulaceous tissue of the grasses; E. MEAD WILCOX, A review and criticism of the botanical curriculum of some of our colleges and universities, from the student's standpoint. The officers elected for the ensuing year are: F. V. COVILLE, *vice-president;* C. J. CHAMBERLAIN, *secretary.*

THE FOLLOWING PAPERS were read before the Botanical Society of America at the recent Pittsburg meeting: MRS. E. G. BRITTON, Studies on reproduction by gemmae of the prothallus of ferns, The genus Sematophyllum (Raphidostegium), The North American species of Trichomanes; N. L. BRITTON, Studies in Cyperus and other Cyperaceae; W. A. CANNON, Maturation divisions in the pollen cells of hybrid cottons (by invitation); J. M. COULTER, The relations of the botanical associations of the country, Parthenogenesis in seed plants; H. C. COWLES, Suggestions for ecological cartography, A comparative study of the sand dunes of the ocean and lake shore (illustrated); B. D. HALSTED (address of past president), Two centuries of American botany; A. S. HITCHCOCK, North American species of Leptochloa; ARTHUR HOLLICK, Fossil ferns from the Laramie group of Florence, Colorado,

Recent investigations in the Pleistocene flora of Maryland (carried out under the auspices of the Maryland Geological Survey, and presented by permission of the state geologist), illustrated; J. E. KIRKWOOD, The embryology of the Cucurbitaceae (by invitation); MISS E. M. KUPFER, Anatomy and physiology of *Baccharis genistelloides;* D. T. MACDOUGAL, The relations of light and darkness to growth and development; W. B. MCCALLUM, The stimulus to heterophylly in *Proserpinaca palustris* (by invitation); W. A. MURRILL, The genus Ganoderma in North America (by invitation); MISS R. J. RENNERT, Dimorphic structure of the phyllodes of *Oxypolis filiformis* (by invitation); P. A. RYDBERG, A study of Astragalus; H. VON SCHRENK, A disease of *Catalpa speciosa;* F. L. STEVENS, Mitosis of the primary nucleus of *Synchytrium decipiens* (by invitation); J. J. THORNBER, A green organism found in water tanks and reservoirs in Arizona (by invitation); JOHN TORREY, The cytology of the secreting epithelium of *Zea Mais* (by invitation); R. H. TRUE, Tea fermentation; L. M. UNDERWOOD, The genus Gymnogramma, and its treatment by English botanists; MISS V. S. WHITE, The Geasters of the United States (by invitation); A. F. WOODS, Some disorganization products of plant cells; CHARLES ZELEMY, The dimensional relations of compound leaves (by invitation). The officers elected for the ensuing year are B. T. GALLOWAY, *president;* F. V. COVILLE, *vice-president;* ARTHUR HOLLICK, *treasurer;* D. T. MACDOUGAL, *secretary;* WILLIAM TRELEASE and L. M. UNDERWOOD, *councilors.*